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# Citizens's perception on stormwater management and use of on-site stormwater detention in Belo Horizonte/Brazil

## *Percepção dos cidadãos sobre o manejo de águas pluviais e o uso de microrreservatórios em Belo Horizonte/MG*

**Pedro de Paula Drumond[1], Priscilla Macedo Moura[1], Talita Fernanda das Graças Silva[1], Juliana Camargos Ramires[2] & Lucas Rogério Vieira Silva[3]**

[1]Departamento de Engenharia Hidráulica e Recursos Hídricos, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brasil
[2]Centro Federal de Educação Tecnológica de Minas Gerais, Belo Horizonte, MG, Brasil
[3]Instituto de Geociências, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brasil

E-mails: pedrubh@yahoo.com.br (PPD), priscilla.moura@ehr.ufmg.br (PMM), talita.silva@ehr.ufmg.br (TFGS), julianacramires@hotmail.com (JCR), lucasrvsgeo@gmail.com (LRVS)

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## ABSTRACT

To mitigate urbanization impacts on the hydrological cycle, Low Impact Development techniques, especially On-site Stormwater Detention - OSD, are applied worldwide. Besides their frequent use, the public knowledge about these techniques and stormwater management is insufficient, particularly in Latin America. Public comprehension about stormwater management and LID techniques lead to more acceptance and engagement. In this sense, the aim of this article is to present the results of interviews about local's perception on stormwater management in Belo Horizonte/Brazil. The results indicate that males and respondents older than 40 years old have more knowledge about stormwater management, as well as higher socioeconomic interviewees. Although the use of OSD is positively perceived, a greater knowledge on urban stormwater does not lead to a greater willingness to co-participate in the stormwater management. Our results provide an overview of city inhabitants' perception of municipal stormwater management and have great potential to help managers.

**Keywords:** Urban drainage; Source control; LID; Drainage tax; Management.

## RESUMO

Para mitigar os impactos da urbanização no ciclo hidrológico, as técnicas de baixo impacto de desenvolvimento (LID), especialmente os microrreservatórios, são utilizadas em todo o mundo. Apesar de seu uso frequente, o conhecimento público sobre essas técnicas e gestão de águas pluviais é insuficiente, principalmente na América Latina. A compreensão do público sobre a gestão de águas pluviais e das técnicas de LID leva a mais aceitação e engajamento. Nesse sentido, o objetivo deste artigo é apresentar os resultados de entrevistas sobre a percepção local dos moradores sobre a gestão de águas pluviais em Belo Horizonte/Brasil. Os resultados indicam que o sexo masculino e os entrevistados com mais de 40 anos possuem mais conhecimento sobre gestão de águas pluviais, assim como os entrevistados com nível socioeconômico mais elevado. Embora o uso de microrreservatório seja percebido positivamente, um maior conhecimento sobre águas pluviais urbanas não leva a uma maior disposição de coparticipar na gestão de águas pluviais. Os resultados fornecem uma visão geral da percepção dos habitantes sobre a gestão municipal de águas pluviais e têm grande potencial para ajudar os gestores da cidade.

**Palavras-chave:** Drenagem urbana; Controle na fonte; LID; Taxa de drenagem; Gestão.

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## INTRODUCTION

Higher runoff volumes, higher and faster peak flows, floods, depletion of groundwater, water quality deterioration are some of the well-documented impacts of urbanization on hydrological cycle (Chocat et al., 2001). Although in developed countries flood protection was mostly achieved, in developing countries, it remains a major issue. Flood problems are aggravated by population growth without stormwater infrastructure, disordered urban planning, occupation of watercourses margins and inadequate approaches for urban drainage system designs (Chocat et al., 2007; Cruz & Tucci, 2008). Climate change is expected to increase flood hazard and worsen this scenario (Chung et al., 2011; Khan et al., 2019; Kundzewicz, 2003).

Source control techniques are part of a more sustainable stormwater management approach that aims at facing urbanization impacts and potential effects of climate change on hydrological response of urban catchments (Chocat et al., 2007; Eckart et al., 2017). These alternative or compensatory drainage techniques, also known as Low Impact Development (LID) or Green Infrastructure (GI), may present distinct terminologies according to local context (Fletcher et al., 2015), but all over are conceived to neutralize the urbanization effects on the hydrological processes through retention and infiltration of runoff, with benefits for life quality and environmental preservation (Dietz, 2007).

Among all source control techniques, On-site Stormwater Detention (OSD) is one of the most commonly applied worldwide (Drumond et al., 2020). It promotes the detention of runoff from impervious areas in order to assure pre-development conditions for peak flow.

Public policies have been created in many cities around the world demanding OSD construction (Tsuchiya, 1978; Urbonas & Glidden, 1983; Kelly & Bryck, 1987; O'Loughlin et al., 1995, 1998; Faulkner, 1999; Zawilski & Sakson, 2002; Petrucci et al., 2011, 2013; Todeschini et al., 2012; van der Sterren et al., 2009; van der Sterren & Rahman, 2015; Drumond et al., 2020). Despite the existence of legal regulations imposing the use of OSD, few studies have evaluated citizens' perception about building these structures in their lots, as well as their perception of the drainage system performance and its problems.

Most studies that investigated factors which influence the adoption (or not) of OSD and other source control techniques by residents have been carried out in developed countries (Kaplowitz & Lupi, 2012; Faehnle et al., 2014; Baptiste et al., 2015; Gao et al., 2016; Coleman et al., 2018; Derkzen et al., 2017). These surveys indicated that the willingness to adopt source control techniques will vary with socio-demographic characteristics, knowledge about the techniques, their benefits, operation and maintenance needs, governance and public engagement and may also be affected by economic incentives (Qi & Barclay, 2021). Furthermore, researchers (Baptiste, 2014;, Baptiste et al., 2015; Faehnle et al., 2014; Kaplowitz & Lupi, 2012) have indicated that citizens' experience should be incorporated as public participation into watershed planning processes.

Regarding studies in developing countries, local perception on source control techniques was assessed in Africa (Feyisa et al., 2014; Gwedla & Shackleton, 2015; Jaber & Shukla, 2007) and Asia (Schetke et al., 2016; Yang, 2008). In Latin America, one of the few studies on this topic was conducted by Costa Junior & Barbassa (2006). They investigated the willingness of the residents of Ponte Seca catchment (Brazil) to adopt OSD, but citizens' knowledge about stormwater management was not assessed.

The success of source control techniques implementation is highly dependent on public understanding, acceptance and engagement (Eckart et al., 2017; Shuster et al., 2008). There is a lack of information on public perception of stormwater problems, and on the willingness to co-participate in the stormwater management in urban areas of developing countries through the adoption of source control techniques in private areas. This may lead to the adoption of ineffective strategies by decision-makers resulting in a waste of, already scarce, public resources and discredit the use of source control techniques in these areas.

Considering the scarcity of research related to the citizen's perception in Brazil on the use of source control techniques for urban drainage, and especially OSD, this paper presents an inedited case study in the municipality of Belo Horizonte / MG. The citizens' willingness to participate in the stormwater management through the implementation of OSD and their knowledge/perception on the performance of the stormwater management were investigated through a door-to-door interview which covered the entire municipality territory.

## METHODS

### Study area

According to The World Bank (2021), Brazil is the largest country in Latin America, with a population of 209.5 million people, which around 85% is urban population. Brazil's Human Development Index – HDI is 0.765, being ranked in the 84$^{th}$ position among countries in the world (United Nations Development Programme, 2019). Despite being in the group of countries classified as high human development and have one of 15 largest economies in the planet, Brazil is among the 10 countries with the greatest income inequality in the world.

In Brazil, there are national guidelines aiming at foster sustainable stormwater management in the cities, such as the Federal Law n$^{o}$ 11.445/2007 (Brasil, 2007). Nonetheless, regulations requiring the application of stormwater source control techniques only exist at municipal level.

Belo Horizonte (BH city) is the capital of Minas Gerais State, located in the southeast region of Brazil, with an estimated population of 2.5 million inhabitants and a surface area of 331 km$^2$ (Instituto Brasileiro de Geografia e Estatística, 2020). The city is administratively divided into nine regions and 81 Municipal Planning Units (MPU), as shown in Figure 01. The predominant climate is humid subtropical, with an average annual rainfall of 1464 mm (Instituto Nacional de Meteorologia, 2009). The rainy season lasts from October to March and the dry season from April to September.

As all Brazilian cities, BH city is responsible for the stormwater management in its territory. The city is often stricken by flash floods due to its topological character and high imperviousness rate.

Although the drainage system is separated from the sewer system, there are many problems related to the discharge of

untreated wastewater into the drainage system and vice-versa and wet weather diffuse pollution (Silva et al., 2010, 2022; Oliveira et al., 2012). Sanitation, water supply and solid waste management are also a responsibility of the municipality. In Belo Horizonte, the water supply and wastewater collection/treatment are charged together, by monthly volume. The solid waste management is charged annually together with other municipal fees. The municipality does not charge a specific fee for providing urban drainage service whose maintenance and expansion is mainly funded by municipal taxes. Municipal policy concerning stormwater management set public participation in formulating related policies, planning and controlling of provided services. However, effective participation and democratic social control are still weak (Oliveira et al., 2012).

Even though BH city was the first Brazilian city to include OSD in municipal policy (Municipal Law n° 7.166/96 - Belo Horizonte, 1996), there is a lack of knowledge about the citizen's perception on the adoption of such storage devices in their lots. Rubinger (2008) reported that BH city residents do not have a clear understanding about the concept of stormwater management and most of them cited the government (the municipality or the state) as responsible for the service. However, the author reported some references to the populations' responsibility as well.

## Sample

The survey sample is based on BH city population which was 2,375,151 inhabitants in 2010 according to the census (Instituto Brasileiro de Geografia e Estatística, 2017). For this study, only citizens older than 18 years were considered as potential respondents, which represent 73.37% of BH city population (Instituto Brasileiro de Geografia e Estatística, 2017). The minimum sample size was 300 as provided by Equation 1 (Veiga, 2003), with a 95% confidence level and ± 5% margin of error. In total, 337 interviews were performed following a proportional allocation given by the number of residents in every MPU. MPU population and number of respondents are presented in Appendix A.

$$n_A = \frac{NZ^2PQ}{e^2(N-1)+Z^2PQ} \quad (1)$$

Where: $n_A$ = sample size; Z = standard normal random variable (Z = 1.96 for 95% confidence interval); P = population proportion in the study (0.7337); Q = non-occurrence proportion (0.3252); e = sample error (0.05); N = population (2,375,151 inhabitants).

## Survey

The survey was carried out through a door-to-door interview from October 2017 to March 2018 by three trained volunteers. The survey was composed of 24 closed-ended questions, elaborated by the authors, which assess the knowledge of respondents about stormwater management systems in BH city regarding its operation, funding, responsibility and main problems. The survey also aimed to investigate their knowledge about OSDs and their willingness to participate in the stormwater management in the city through the implementation of such device in their lots. Questions aiming at socio-demographic characterization were also applied. A brief description of the survey follows, and the form used during interviews is presented in Appendix B.

### Socio-demographic characterization

This part of the survey aimed at obtaining information on location, age, gender, educational level and economic status of the respondents (*Questions 1 to 3*). Location considered the nine administrative regions of BH city (Figure 1). Six age classes were established: from 18 to 30 years; 31 to 40 years; 41 to 50 years; 51 to 60 years; 61 to 70 years and older than 70 years. Educational level included no formal education/incomplete elementary; complete elementary/incomplete middle school; complete middle school/incomplete high school; complete high school/incomplete undergraduate level; complete undergraduate level. The socioeconomic profile was based on the Brazilian Economic Classification Criteria (Associação Brasileira de Empresas de Pesquisa, 2018) which seeks to estimate the purchase potential of consumer goods and services by residents in urban areas and classifies them in terms of socioeconomic strata from A to D classes, in decreasing order of socioeconomic status. Through the answers of questions 1, 2 and 3 (form in Appendix B), the average household income for each class was estimated according to Associação Brasileira de Empresas de Pesquisa (2018) as $6.395,92 (A), $2.845,62 (B1), $1.469,37 (B2), $812,52 (C1), $463,41 (C2) e $194,02 (D).

### Knowledge on stormwater management system funding

The purpose of this part of the form was to assess citizens' perception on funding responsibility to expand and maintain the stormwater management system (*Questions 7 and 20*). Respondents' knowledge about a specific fee for providing urban drainage services was also assessed (*Question 21*).

### Knowledge on drainage system performance and its main problems

Regarding the urban drainage system performance the survey included questions to verify the knowledge of Belo Horizonte's citizens about the drainage system (drain of stormwater only or mixed with wastewater, *Question 8*), its connection to streams and rivers (*Question 14*) and the design and operation of residential stormwater system (*Question 9*).

The understanding on urban drainage problems was also assessed. The respondents answered questions about three aspects: the existence of floods nearby their residence (*Question 15*), the period of the year when floods are more frequent (*Question 16*) and about the relationship between floods and the increase of impervious areas in the cities (*Questions 17 and 18*).

### Knowledge on OSDs

This part of the survey assessed whether citizens know the OSD technique (*Question 10*), whether they have OSD in their lots (*Question 11*) and whether respondents were aware of any performance problem of the OSD which would indicate a

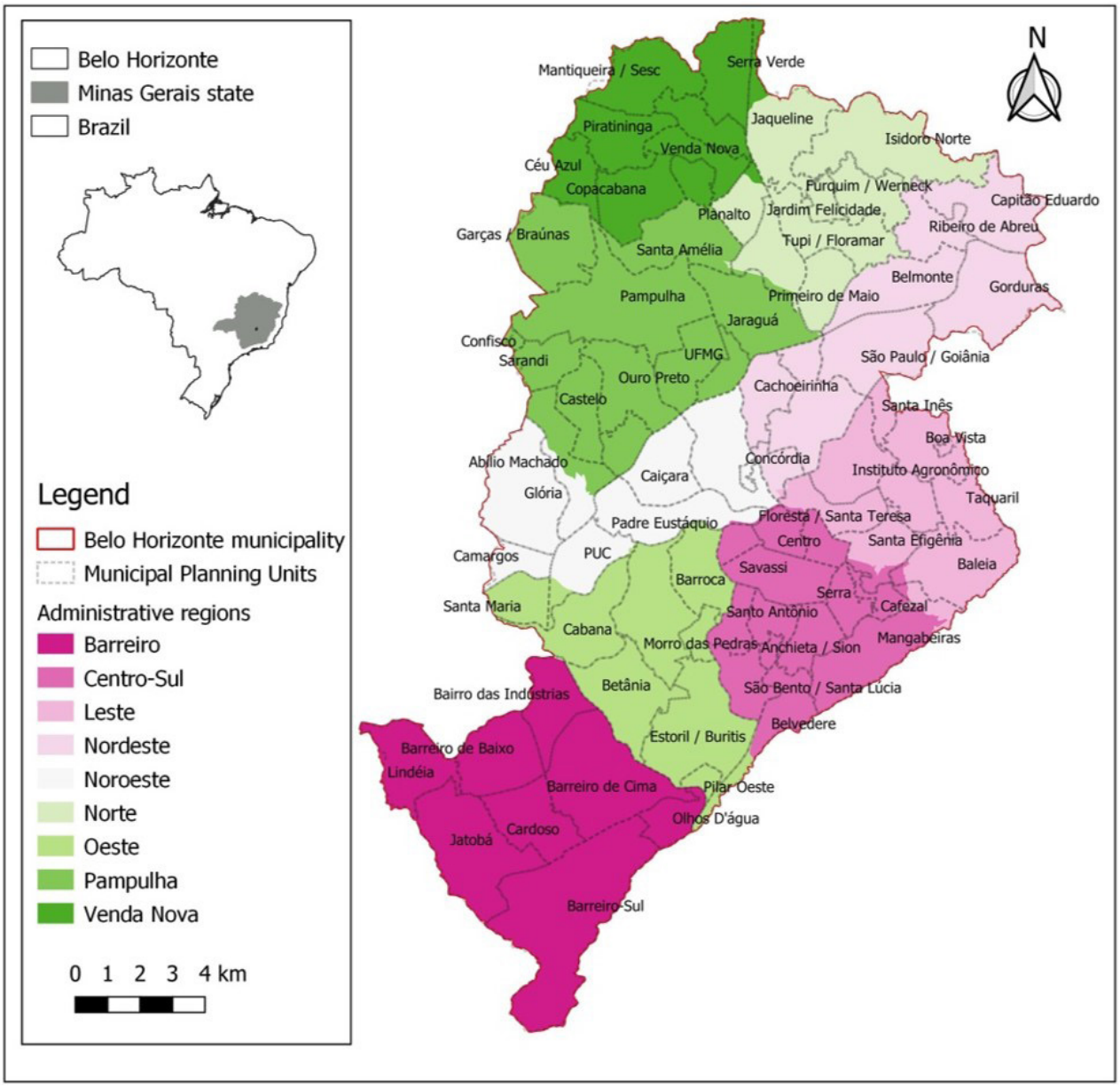


**Figure 1.** Administrative regions and Municipal Planning Units (MPU) of Belo Horizonte.

malfunction of the storage device (*Question 13*). Among respondents owning an OSD, the survey also verified whether the storage device was used for purposes other than controlling runoff, which could indicate that the respondent had a rainwater tank rather than an OSD (*Question 12*).

### Willingness to participate in stormwater management

The willingness to participate in the stormwater management in BH city was evaluated through respondent's views about charging drainage services (*Question 22*), the respondent's interest to install an OSD (i) without economic incentive from the municipality (*Question 19*); (ii) upon a reduction in the municipal tax (*Question 23*); and (iii) upon exemption from the payment of a hypothetical drainage fee (*Question 24*).

## Analysis

Based on survey data, analysis were carried out to define the percentages of the sample referring to demographic characteristics, knowledge about stormwater management and citizen's willingness to construct an OSD. The demographic characteristics distribution of the respondents was compared to those of BH city using Chi-square test of independence. The analysis was performed using census data (Instituto Brasileiro de Geografia e Estatística, 2011) based on gender, age and educational level.

A score was assigned to all survey questions that refer to the respondent knowledge about funding stormwater management system (*Questions 7, 20 and 21*), the drainage system performance and its main problems (*Questions 8, 9, 14, 16, 17 and 18*) and the OSD device (*Question 10*). For every answer demonstrating knowledge about funding a value of "1" was assigned and otherwise, a value

of "0" was assigned. The values were summed in order to attribute an aggregated knowledge score to all respondents which were then divided into two groups, above and below the median score.

Chi-square test was used to compare nominal variables (socio-demographic characteristics) between the two groups of residents. For every variable (gender, educational level, location, economic status and age), data was checked for normality using Shapiro-Wilk test. Because the majority of datasets presented evidence of non-normal distribution, Mann-Whitney U test was used to compare the median value of the knowledge score between two classes (e.g. gender) while the Kruskal-Wallis test was applied to compare the median value of the knowledge score between three or more classes within a given variable (e.g. educational level) followed by Dunn's pairwise comparison.

For every question about the resident willingness to participate in the stormwater management (*Questions 19, 22, 23 and 24*) and for the question about owning an OSD device (*Question 11*), Chi-square test was also used to investigate the relationship with socio-demographic characteristics. The relationship between the knowledge about the stormwater management and the willingness to participate in it was also assessed. For each of these questions, Mann-Whitney U test was used to compare the median value of the knowledge score between residents that would like to participate in the stormwater management and residents that do not want to.

Statistics were performed using R 3.6.3 software (R Core Team, 2020) through *rstatix* package (Kassambara, 2020), stats package (R Core Team, 2020) and ggplot2 and devtools for plotting figures.

## RESULTS

### Sample demographics

Based on the analysis of the survey data, 49.85% of the total number of respondents were female and 50.15% male. The BH city residents', aged of more than 18 years old, correspond to 54% females and 46% males. Respondents were aged from 18 to 93, with a mean of 54.13 and a median of 56 years old, while BH city inhabitants of that age strata are aged, in mean of 38 and median 39 years old. The largest fraction of respondents was over 60 years old.

The socioeconomic classes' data indicates that most respondents have an average monthly household income between $ 463.41 and $ 1,469.37, representing about 67.66% of the total interviews, a percentage close to 68.2%, indicated by Associação Brasileira de Empresas de Pesquisa (2018) for the same family income range in BH city. Concerning respondents' educational levels, 13% has no formal education/incomplete elementary; 15% has complete elementary/incomplete middle school; 11% has complete middle school/incomplete high school; 30% complete high school/incomplete undergraduate level and 31% has complete undergraduate level, while the respective percentages for BH city's population aged more than 18 years old are 4%, 26%, 15%, 32% and 23%. Figure 2 shows the results regarding age, education and socioeconomic class obtained through data analysis.

Comparing sociodemographic characteristics using Chi-square test showed that gender is the only variable for which respondent sample is representative of BH city census data ($\chi^2[1] = 2.33$, *p-value* = 0.1265). Age ($\chi^2[5] = 178.5$, *p-value* < 0.001), educational level ($\chi^2[4] = 97.15$, *p-value* < 0.001) and economic status ($\chi^2[5] = 69.7$, *p-value* < 0.001) showed different distribution between respondent sample and BH city population which means that extrapolations for these variables should be performed with care. The authors assume that the time the interviews were carried out (from 8 am to 5 pm) may have influence the respondent sociodemographic profile, since most part of the economically active inhabitants would be at work. Issues to obtain representative samples in this type of survey have also been reported in previous researches in other study sites (Baptiste et al., 2015; Derkzen et al., 2017).

### General context

The summary of results on the respondents' perception of stormwater management is presented in Table 1. All percentages showed in Table 1 are related to the total number of responders (n = 337), except for questions 12 and 13 whose percentages refer to the responders that answered "Yes" to the question 11.

Around half of the respondents knows that the drainage system drains stormwater only. The same percentage of respondents knows what an OSD is. Approximately 60% of respondents answered that the increase of impervious areas is related to flooding problems.

The results on the installation of OSD indicated that most respondents would install the structure on their lots regardless of whether there were financial incentives from the municipality. According to Figure 3, 83% of respondents would implement the OSD in the lot to reduce flooding problems, 75% would install the drainage structure if the municipal tax value were reduced by

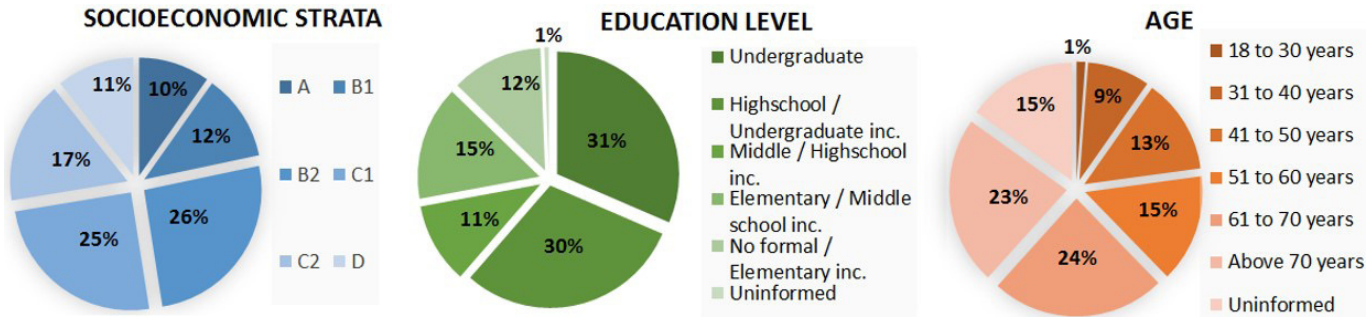


**Figure 2.** Results on monthly income range, educational level and age of respondents.

**Table 1.** Results on the respondents' perception of the drainage system. All percentages are related to the total number of responders (n = 337), except questions 12 and 13 whose percentages refer to the responders that answered "Yes" to the question 11.

| # | Question | Percentages: Yes | No | Do not know |
|---|---|---|---|---|
| 7 | Do you pay have access to stormwater drainage system? | 14.2 | 40.4 | 45.4 |
| 8 | Do you know that the drainage system drains stormwater only? | 47.8 | 43.3 | 8.9 |
| 9 | Do you know how the stormwater drains in your lot and the place where the rainwater is discharged? | 63.5 | 34.4 | 2.1 |
| 10 | Do you know what On-site Stormwater Detention (OSD) or a residential detention tank is? | 49.5 | 48.1 | 2.4 |
| 11 | Is there an On-site Stormwater Detention or a residential detention tank in your lot? | 7.1 | 92.3 | 0.6 |
| 12 | Is the stormwater used? | 70.8 | 29.2 | |
| 13 | Is there any performance problem with the On-site Stormwater Detention? | 8.3 | 91.7 | |
| 14 | Do you know that the drainage system discharge stormwater into watercourses? | 58.7 | 41.3 | |
| 15 | Are there any flooding problems near your home? | 30.9 | 69.1 | |
| 16 | Do you know which months of the year floods are most frequent? | 81.9 | 18.1 | |
| 17 | Do you know that impervious areas in the lots increase the amount of stormwater into drainage network? | 58.7 | 41.3 | |
| 18 | Do you know if the increase of impervious areas is related to flooding problems? | 61.7 | 38.3 | |
| 20 | Do you know that the municipality pays the costs of implementing, maintaining and cleaning the city's urban drainage systems? | 54.3 | 45.7 | |
| 21 | Do you know there is a law that authorizes charging for the drainage services? | 46.3 | 53.7 | |

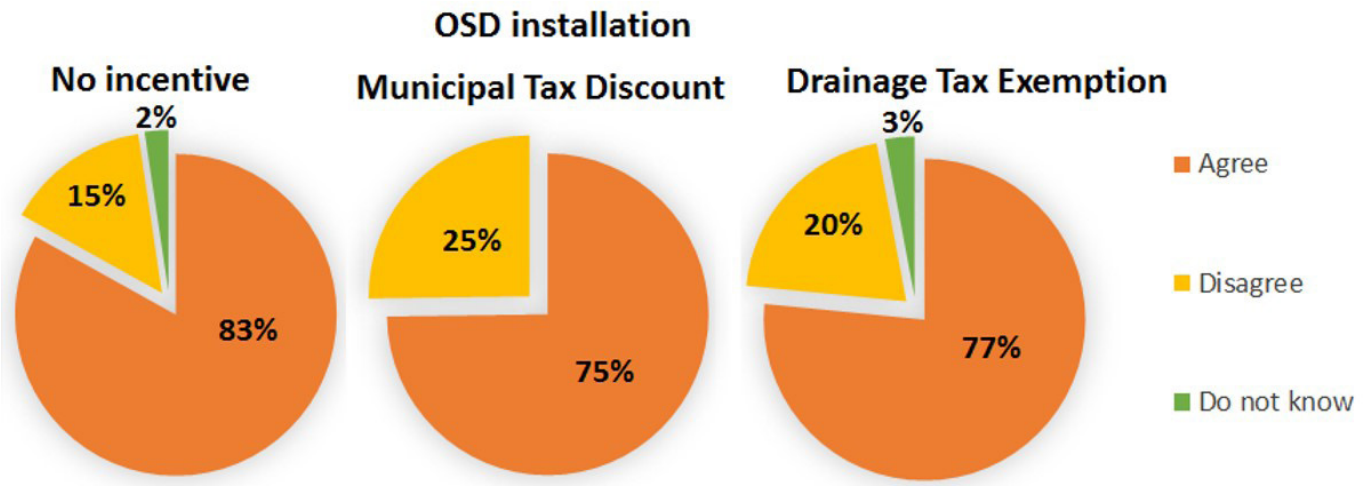


**Figure 3.** Results on the willingness to install the OSD in the respondent's lot.

10% and 77% would build the drainage device if there was an exemption from payment of the drainage fee.

## Citizen's knowledge about stormwater management in Belo Horizonte

The respondents answered ten questions which assessed their knowledge about funding, performance and problems of the stormwater management in Belo Horizonte and about OSD devices. The maximum, minimum and median values of knowledge score were, respectively, 10, 0 and 5. Figure 4 shows the knowledge score distribution and in Figure 5 the number of answers demonstrating knowledge per question is presented. Only 68 respondents (20%) know that the municipality could charge citizens for providing drainage service and only 136 respondents (40%) actually know that drainage service in Belo Horizonte is not charged. A greater number of respondents knows the rainwater flow path inside their lots (214 respondents, 64%) and is aware that increasing imperviousness in the city worsens floods (208 respondents, 62%). The other questions had an intermediary number of answers indicating knowledge.

The respondents were divided in two groups, those with knowledge score greater than 5 (median score value) and those with the knowledge score smaller than 5. Among socio-demographic variables, only gender ($\chi^2[1] = 15.2$, *p-value* < 0.001) and age ($\chi^2[5] = 18.2$, *p-value* = 0.003) showed statistically significant relationship with respondent groups. When comparing median score values (Figure 6a), males had a score greater than females (Mann-Whitney U test, *p-value* < 0.001), younger respondents aged between 18 and 30 years had a score smaller (Figure 6c) than respondents older than 40 years (Kruskall-Wallis and Dunn tests, *p-values* < 0.012). Although Chi-test showed no significant relationship between socioeconomic status and the respondent groups, median score of the respondents in class A is greater (Figure 6b) than the median score of respondents in class D (Kruskall-Wallis test, *p-value* = 0.02 and Dunn test, *p-value* < 0.001). Median score values were not significant different between classes of other socio-demographic variables.

## Citizens' willingness to participate in the stormwater management in Belo Horizonte

Respondents' knowledge score was assessed together with their answers for all questions involving the willingness to participate in the stormwater management, either through the payment of a drainage fee (*Question 22*) or through the implementation of an OSD device with (*Questions 23 and 24*) or without (*Question 19*) an economic incentive. Median values of knowledge score were not significantly different between those who would participate in the stormwater management and those that would not participate.

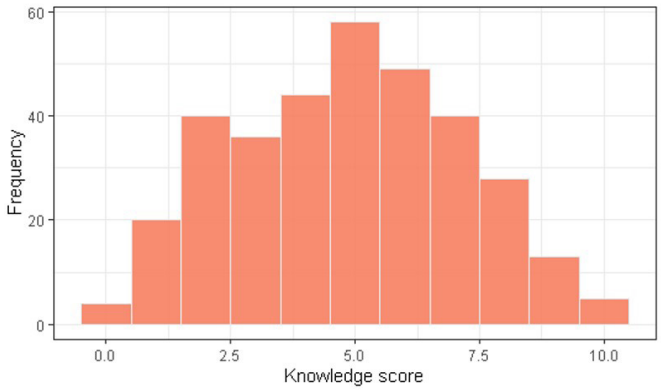


**Figure 4.** Histogram of knowledge score between respondents.

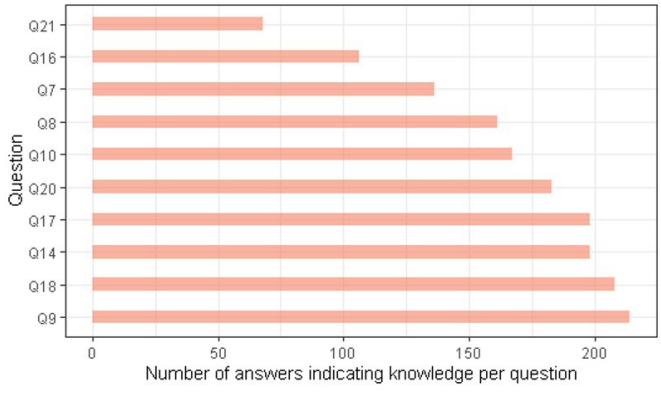


**Figure 5.** Number of answers indicating knowledge per question.

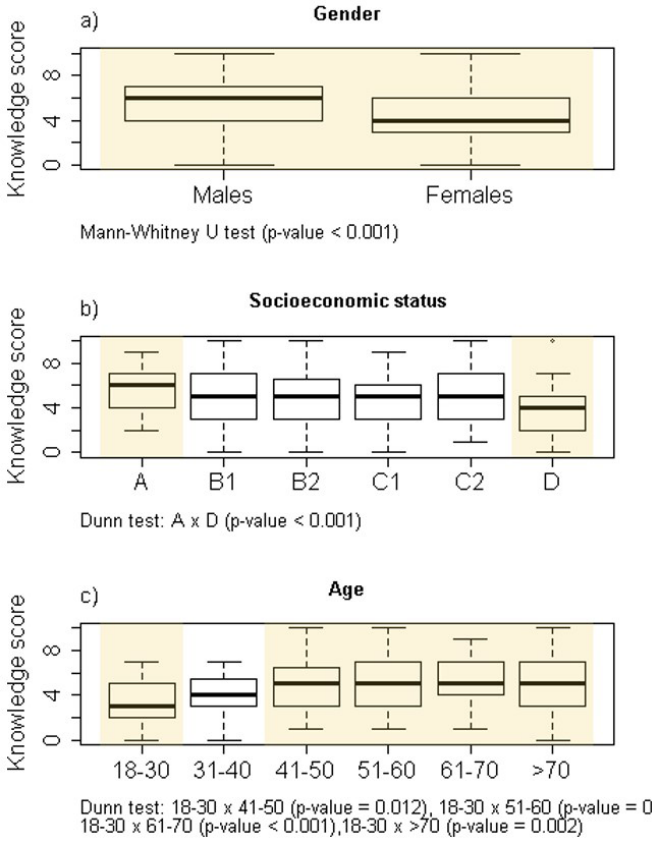


**Figure 6.** Knowledge scores for socio-demographic variables which presented significant different median values between classes.

However, median value of knowledge score was significantly different between respondents owning an OSD device and those that do not own it (Mann-Whitney U test, *p-value* = 0.01).

The most part of the respondents declared to not own an OSD device (n = 313), but this number was significantly higher ($\chi^2[1] = 7.5$, *p-value* = 0.006) between female respondents (n = 163) than between males (n = 150). The relationship between other socio-demographic variables and owning an OSD could not be assessed due to the small number of respondents (less than 5) who owns an OSD in several classes of the nominal variables.

No relationship was found between gender, educational level, location, socioeconomic status or age and the agreement with a drainage charge. Gender is not related to the willingness of implementing an OSD in order to help avoiding flooding, but educational level ($\chi^2[4] = 18.2$, *p-value* = 0.001) and socioeconomic class ($\chi^2[5] = 24.0$, *p-value* < 0.001) are. The higher educational level, the greater number of respondents that would implement an OSD to reduce flooding problems in the city (Figure 7a) and the higher socioeconomic status, the greater number of respondents that would implement an OSD (Figure 7b). The relationship between location and age with the implementation of an OSD could not be assessed due to the small number of respondents (less than 5) in some classes of these variables.

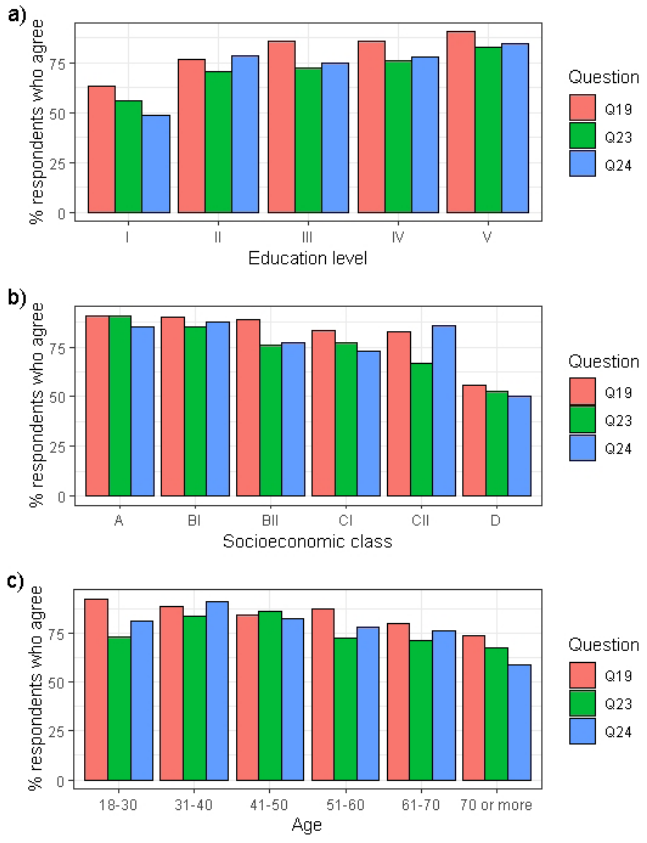


**Figure 7.** Percentage of respondents who agree with the implementation of an OSD to reduce flooding problems (Q19); whether a 10% discount on the municipal tax is provided (Q23) and; whether an exemption of a hypothetical drainage fee (Q24) considering educational level (a), socioeconomic class (b) and age (c). In a) I - no formal education/incomplete elementary; II - Elementary/incomplete middle school; III- Middle school/ incomplete high school; IV - High school/incomplete undergraduate and; V - Undergraduate.

Educational level ($\chi^2[4] = 12.1$, *p-value* = 0.02) and socioeconomic status ($\chi^2[5] = 18.6$, *p-value* = 0.001) also influences the willingness to implement an OSD upon a reduction of 10% in the municipal tax. If the educational level and economic status are high, the greater are the number of respondents that would implement an OSD under such municipal tax reduction (Figure 7a and b). Gender, location and age showed no significant influence for this viewpoint of respondents.

Educational level ($\chi^2[4] = 22.0$, *p-value* < 0.001), socioeconomic status ($\chi^2[5] = 21.6$, *p-value* < 0.001) and age ($\chi^2[5] = 16.5$, *p-value* = 0.005) were related to the willingness to implement an OSD upon an exemption in a hypothetical drainage fee. A greater part of respondents with undergraduate level (85%) is willingness to implement an OSD under such assumption than respondents which had no formal education/incomplete elementary (49%). (Figure 7a). Within other educational levels, this percentage varies between 75 and 78% (Figure 7a). Within socioeconomic status, classes A, B1 and C2 presented from 85% to 88% of respondents which would implement and OSD against 50% in class D and 77% and 73%, respectively in classes B2 and C1 (Figure 7b). Gender showed no significant influence for this viewpoint of respondents, location and age influence could not be assessed due to the small number of respondents (less than 5) in some classes of this variable. Nonetheless, younger respondents (between 18 and 50 years old) are more favorable to implement an OSD than respondents older than 70 years (Figure 7c).

## DISCUSSION

### Citizen's knowledge about stormwater management in Belo Horizonte

The results showed that knowledge on stormwater management in BH city is related to gender, age and socioeconomic status. Females and young people are less aware of stormwater issues in BH city when compared to males and respondents older than 40 years old, respectively. In a survey about stormwater runoff management in Appalachia (United States), Cockerill et al. (2019) also found that males are more likely aware of stormwater runoff definition than females, as well as older respondents compared to younger ones. On the contrary, in Syracuse (New York, United States), socio-demographic variables were not related to knowledge about stormwater control techniques (Baptiste et al., 2015). We postulate that in BH city the further understanding of males and respondents older than 40 years about stormwater management is related to a greater lived experience in dealing with stormwater issues in their households or outside them.

Median knowledge score was significant higher for respondents within A socioeconomic strata than in D strata, while no significant difference was found between respondents with different educational level. This may be related to citizens in higher socioeconomic strata having more access to information about stormwater management provided from outside the formal school system.

As indicated in Table 1, a large percentage of interviewees do not know that the drainage system drains stormwater only; what an OSD is and the increase of impervious areas is related to flooding problems. According to Cockerill et al. (2019), taken as a whole, their results suggest that public knowledge and perceptions about stormwater management remain an enigma. There are clearly complicated relationships regarding what people know, what they do on their own property and how they feel about stormwater management generally. Their findings do suggest that there is opportunity for educating people about what runoff is, where it goes, and what its impacts are for stream quality.

It is important that BH managers create educational campaigns to make the population aware of the drainage system functioning, the causes of flooding, the need to participate in drainage management on a residential scale and to have a self-sustainable system. Providing knowledge to the population is an important tool to ensure the sustainability of sanitary interventions.

## Citizens' willingness to participate in the stormwater management in Belo Horizonte

Unlike our expectations, results showed that greater knowledge about urban stormwater was not related to a greater willing to co-participate in its management. Actually, literature shows no consensus about citizens' understanding of stormwater management and willingness to contribute for it. Yu et al. (2019) found that a higher cognition level about green infrastructures (GI) was related to a stronger willingness to participate in the implementation of GI in private spaces in Shanghai (China) and Baptiste et al. (2015) argued that environmental knowledge would only be an important factor for its implementation in Syracuse (New York, United States) whether economic incentives were also provided. In the opposite direction, general knowledge about runoff was reported to not influence the odds of citizens having implemented GI/LID techniques in Appalachia in the United States (Cockerill et al., 2019). Still in the United States, residents of Baltimore with greater watershed knowledge were positively associated with supporting taxes and volunteering for watershed improvement, while in Phoenix no significant association were found (Locke et al., 2020).

In BH city, those respondents who already have an OSD, though in a smaller number especially between females, were associated to a greater knowledge score. This is consistent with findings from previous studies, such as Gao et al. (2016) that verify an association between rain barrel adopters, positive attitudes towards the environment and good knowledge about urban conservation practices.

Concerning socio-demographic variables, education level and socioeconomic status were both related to willingness to adopt an OSD device with or without economic incentives. In the United States, higher incomes were also associated to a stronger willingness to adopt rain barrels in Chicago (Ando & Freitas, 2011) and to implement GI in Appalachia (Cockerill et al., 2019). In BH city residents within higher socio-economic strata are more willing to adopt an OSD device likely because it would not impact their financial commitments or even basic needs, as may be the case of residents in lower socio-economic strata. When considering a broader spectrum of green infrastructures techniques, surveys in other cities showed that willingness to implement them may be higher among of citizens with low socio-economic status because they have stronger willingness to improve living condition (Yu et al., 2019), especially under economic incentive possibilities (Baptiste et al., 2015).

Although it was not possible to apply Chi-square test to assess relationship between age and willingness to implement an OSD device without any incentive and considering an exemption of a hypothetical drainage fee, a distinct behavior was observed among younger (from 18 to 30 years old) and older (more than 70 years old) respondents. Young people are more leaning to implement OSDs and participate in stormwater which has been also reported elsewhere (Cockerill et al., 2019; Coleman et al., 2018; Locke et al., 2020). Interestingly, in Shanghai (China) older people with more available time were more willing to participate in the implementation of GI in private spaces than younger residents (Yu et al., 2019).

No relationship between socio-demographic variables and willingness to pay a drainage fee was found in this study. According to Derkzen et al. (2017), socio-cultural valuation as applied in their study revealed more nuances than economic valuation alone would. However, in Baltimore/United States supporting of a hypothetical watershed improvement tax was higher between respondents with higher incomes and education levels (Locke et al., 2020). These different results show that local studies such as this one are important to assess specific issues in the region and that managers cannot simply "import" study results from other countries.

Location showed no relevance in all analysis performed in this study. On one hand, this may be related to an inadequacy of the spatial unit selected for analysis. The administrative regional is probably too large and heterogeneous in terms of stormwater impacts on residents. On the other hand, Ando & Freitas (2011) who conducted a research about rain barrels adoption in a municipal scale (Chicago, United States) found that location of flood events was not related to rain barrel adoption in the city. Future studies in BH city should investigate the influence of different spatial scales on the residents' perception about stormwater management.

Based on the results of citizen's willingness to participate in the stormwater management, the population is interested in participating in the stormwater management. However, there are some questions that need to be explored, such as: What is the profile of target public that the decision makers should focus in order to have a larger OSD adoption? How is the profile of citizen most likely to adopt OSD if more information/incentive is given?

One line of reasoning that could help answer these questions is to start charging for public urban stormwater drainage and management services provision, as provided for in Federal Law No. 11.445/07. If the charge is based on the percentage of impervious area on the lot, an aspect that directly influences the functioning of drainage system, citizens who occupy a larger area and generally have higher incomes could be the target public profile to be reached. It could be defined that in case of OSD or other source control technique adoption, the owner may be exempted from charging the drainage fee. As previously described,

respondents in higher socioeconomic strata were associated to a stronger willingness to adopt an OSD device.

## CONCLUSION

Based on the results of 337 interviews performed, which represents a confidence level around 95% and ± 5% margin of error, the knowledge about stormwater management in BH city is related to gender, age and socioeconomic status. No relationship between socio-demographic variables and willingness to pay a drainage fee was found. Females and young people are less aware of stormwater issues in BH city when compared to males and respondents older than 40 years old. Also, respondents in higher socioeconomic strata had more knowledge about stormwater management.

The survey indicated that greater knowledge about urban stormwater was not related to a greater willing to co-participate in its management. However, in general, respondents have shown positive perceptions of usage of On-site Stormwater Detention and willingness to adopt it was related to educational level and socioeconomic status.

The results here presented provide an overview of the BH city inhabitants' perception of the municipal stormwater management and have great potential to help municipality managers in choosing target public and defining strategies to foster OSD adoption in the city. It is important that BH managers create an educational campaign to make the population aware of the functioning of the drainage system, the causes of flooding, the need to participate in drainage management on a residential scale and to have a self-sustainable system.

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## Authors contributions

Pedro de Paula Drumond: Conceptualization; Methodology; Data Collection; Analysis; Investigation; Writing – original draft; Project administration.

Priscilla Macedo Moura: Methodology; Analysis; Investigation; Writing – review and editing; Supervision.

Talita Fernanda das Graças Silva: Conceptualization; Methodology; Software; Validation; Analysis; Investigation; Writing – original draft; Supervision.

Juliana Camargos Ramires: Methodology; Data Collection; Investigation.

Lucas Rogério Vieira Silva: Methodology; Data Collection; Investigation.

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## APPENDIX A. TOTAL POPULATION AND NUMBER OF INTERVIEWS CONDUCTED PER MPU IN BELO HORIZONTE.

| Region | MPU Name | Population (Interviews) | Region | MPU Name | Population (Interviews) |
|---|---|---|---|---|---|
| Centro-Sul | Barro Preto | 6.183 (1) | Venda Nova | Mantiqueira/Sesc | 46.100 (7) |
| | Centro | 16.592 (2) | | Serra Verde | 18.947 (3) |
| | Francisco Sales | 8.553 (1) | | Piratininga | 50.771 (7) |
| | Savassi | 53.613 (8) | | Jardim Europa | 25.054 (4) |
| | Prudente de Morais | 18.833 (3) | | Venda Nova | 17.659 (3) |
| | Santo Antônio | 27.500 (4) | | Céu Azul | 29.842 (4) |
| | Anchieta/Sion | 43.229 (6) | | Copacabana | 58.724 (8) |
| | Serra | 22.879 (3) | | São João Batista | 15.334 (2) |
| | Mangabeiras | 7.378 (1) | Barreiro | Bairro das Indústrias | 10.725 (2) |
| | São Bento/Sta. Lúcia | 13.044 (2) | | Lindéia | 50.396 (7) |
| | Belvedere | 9.729 (1) | | Barreiro de Baixo | 42.000 (6) |
| | Barragem | 15.353 (2) | | Barreiro de Cima | 58.465 (8) |
| | Cafezal | 27.721 (4) | | Jatobá | 71.497 (10) |
| Leste | Instituto Agronômico | 42.819 (6) | | Cardoso | 38.702 (5) |
| | Boa Vista | 46.680 (7) | | Olhos D'Água | 7.613 (1) |
| | Floresta/Santa Tereza | 34.091 (5) | | Barreiro-Sul | 3.184 (1) |
| | Pompéia | 23.546 (3) | Oeste | Cabana | 64.658 (9) |
| | Taquaril | 40.194 (6) | | Jardim América | 72.906 (10) |
| | Santa Efigênia | 40.753 (6) | | Barroca | 49.441 (7) |
| | Baleia | 8.700 (1) | | Morro das Pedras | 17.963 (3) |
| | Mariano de Abreu | 4.499 (1) | | Betânia | 44.199 (6) |
| | Santa Inês | 9.669 (1) | | Estoril/Buritis | 35.838 (5) |
| Pampulha | Garças/Braúnas | 8.448 (1) | Nordeste | Capitão Eduardo | 8.523 (1) |
| | Santa Amélia | 38.441 (5) | | Ribeiro de Abreu | 24.829 (4) |
| | Pampulha | 12.813 (2) | | Belmonte | 45.134 (6) |
| | Jaraguá | 36.098 (5) | | Gorduras | 22.406 (3) |
| | Sarandi | 27.723 (4) | | São Paulo/Goiânia | 62.563 (9) |
| | Castelo | 25.360 (4) | | Cristiano Machado | 77.750 (11) |
| | Ouro Preto | 23.563 (3) | | Cachoeirinha | 32.800 (5) |
| | UFMG | - (0) | | Concórdia | 16.942 (2) |
| | São Francisco | 8.409 (1) | Noroeste | Glória | 66.159 (9) |
| | Confisco | 4.461 (1) | | Abílio Machado | 43.519 (6) |
| Norte | Jaqueline | 36.122 (5) | | Jardim Montanhês | 15.343 (2) |
| | Isidoro Norte | 9.400 (1) | | Caiçara | 39.280 (6) |
| | Furquim Werneck | 8.768 (1) | | Antônio Carlos | 54.732 (8) |
| | Planalto | 17.685 (3) | | Padre Eustáquio | 50.681 (7) |
| | São Bernardo | 34.148 (5) | | Camargos | 4.489 (1) |
| | Tupi/Floramar | 56.555 (8) | | PUC | 32.140 (5) |
| | Primeiro de Maio | 33.593 (5) | | Santa Maria | 20.435 (3) |
| | Jardim Felicidade | 16.937 (2) | | Prado Lopes | 7.326 (1) |

Fonte: PBH, 2017.

## APPENDIX B. UNIVERSIDADE FEDERAL DE MINAS GERAIS – ESCOLA DE ENGENHARIA.

PROGRAMA DE PÓS-GRADUAÇÃO EM SANEAMENTO, MEIO AMBIENTE E RECURSOS HÍDRICOS - SMARH
SURVEY QUESTIONNAIRE
Interview date:
Name: Birth date:
Address: Administrative Region:
1 – Items you have in the house: Quantities of items from 1 to 4

| **( ) Bathrooms** | **( ) Domestic cleaner** |
|---|---|
| ( ) Car | ( ) Computer |
| ( ) Dishwasher | ( ) Fridge |
| ( ) Freezer | ( ) Washing machine |
| ( ) DVD player | ( ) Microwaves |
| ( ) Motorcycle | ( ) Tumble dryer |

2 – Education level: ( ) No formal education/Incomplete elementary; ( ) Complete elementary/Incomplete middle school; ( ) Complete middle school /Incomplete high school; ( ) Complete high school/Incomplete undergraduate level; ( ) Complete undergraduate level.

3 – Public services: ( ) Piped water supply ( ) Paved street

4 – Do you pay to have access to drinking water?

□ Yes □ No □ Do not know

5 - Do you pay to have access to sewage collection and treatment?

□ Yes □ No □ Do not know

6 - Do you pay to have access to waste collection and disposal?

□ Yes □ No □ Do not know

7 - Do you pay to have access to stormwater drainage system?

□ Yes □ No □ Do not know

8 – Do you know that the drainage system drains stormwater only?

□ Yes □ No □ Do not know

9 – Do you know how the stormwater drains in your lot and the place where the rainwater is discharged?

□ Yes □ No □ Do not know

10 – Do you know what On-site Stormwater Detention (OSD) or a residential detention tank is?

□ Yes □ No □ Do not know

11 – Is there an On-site Stormwater Detention or a residential detention tank in your lot?

□ Yes □ No □ Do not know

12 – Is the stormwater used?

□ Yes □ No □ Do not know

13 – Is there any performance problem with the On-site Stormwater Detention? Which?

□ Yes □ No □ Do not know

14 – Do you know that the drainage system discharge stormwater into watercourses?

□ Yes □ No

15 – Are there any flooding problems near your home?

□ Yes □ No □ Do not know

16 – Do you know which months of the year floods are most frequent? Which ones?

□ Yes □ No Months:

17 – Do you know that impervious areas in the lots increase the amount of stormwater into drainage network?

□ Yes □ No

18 – Do you know if the increase of impervious areas is related to flooding problems?

□ Yes □ No

19 – If the implementation of On-site Stormwater Detention in places with impervious areas would reduce flooding problems, would you install it in your lot?

□ Yes □ No □ Do not know

20 – Do you know that the municipality pays the costs of implementing, maintaining and cleaning the city's urban drainage systems?

□ Yes □ No

21 - Do you know that there is a law that authorizes charging for the drainage services?

□ Yes □ No

22 – Are you in favor of charging drainage services to reduce flooding problems? How much would you pay per month?

□ Yes □ No

( ) $ 1.37 ( ) $ 2.74 ( ) $ 5.48 ( ) $ 8.22 ( ) More than $ 8.22

23 – If the municipality provides a 10% discount on the municipal tax to the owners of lots that install an OSD, would you install it?

□ Yes □ No

24 – If there was a charge for drainage services and an exemption from payment in cases where the OSD was installed in the lots, would you install it?

□ Yes □ No □ Do not know