

Disposal of pharmaceutical wastes by the population of an outcrop area of the Guarani Aquifer System in Southern Brazil

Descarte de resíduos de medicamentos pela população de uma área de afloramento do Sistema Aquífero Guarani no Sul do Brasil

Eliminación de residuos de medicamentos por parte de la población de un afloramiento del Sistema Acuífero Guaraní en el sur de Brasil

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Abstract

Pharmaceutical waste is considered emerging pollutant that can contaminate water sources and underground water, besides is serious problem for waste management in Brazil. The objective of this study was to evaluate the pharmaceutical consumption for human use and the way expired and unused medicines are disposed by the population. The study was carried out in two neighborhoods of the Lages, under outcrop of the Guarani Aquifer, in southern Brazil. In this descriptive and quantitative study, data collection occurred between August and October of 2018 via a questionnaire completed by 309 participants. The questions addressed about sociodemographic data, information on the medicine consumption, disposal of pharmaceuticals residue and about the basic sanitation in the neighborhood. The pharmaceuticals class most used were anti-hypertension and diuretics, indicating an elevated occurrence of non-transmittable chronic illnesses. About 68% of participants stated that there are leftovers of medications after medical treatment and 70.2% that there is expired medication at household. The disposal of leftover and expired pharmaceutical was in domestic waste, followed by discharged into domestic sewage. Only a small percentage (<15%) of the participants adequately dispose of their medication waste. The inadequate disposal of household pharmaceutical in the study area can result in contamination by chemical substances of the Guarani Aquifer and superficial waters.

Keywords: Environmental Impact; Pharmaceutical Residues; Public Health; Water Contamination.

Resumo

Resíduo de medicamento é considerado poluente emergente que pode contaminar fontes de água e lençóis freáticos, além de ser um sério problema para o gerenciamento de resíduos no Brasil. O objetivo deste estudo foi avaliar o uso de medicamentos de uso humano e a forma como os medicamentos vencidos e em desuso são descartados pela população. O estudo foi realizado em dois bairros de Lages, sob afloramento do Aquífero Guarani, no sul do Brasil. Neste estudo descritivo e quantitativo, a coleta de dados ocorreu entre agosto e outubro de 2018 por meio de um questionário respondido por 309 participantes. As questões abordavam sobre dados sociodemográficos, o uso de medicamentos, a destinação dos medicamentos vencidos e em desuso e o sobre o saneamento básico do bairro. As classes de medicamentos mais utilizadas foram os anti-hipertensivos e os diuréticos, indicando elevada ocorrência de doenças crônicas não transmissíveis. Cerca de 68% dos participantes afirmaram que há sobras de medicamentos após o tratamento médico e 70,2% que há medicamentos vencidos em casa. O descarte de sobras e medicamentos vencidos é

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realizado no resíduo doméstico, seguido pelo descarte no esgoto doméstico. Apenas uma pequena porcentagem (<15%) dos participantes descartam adequadamente seus resíduos de medicamentos. O descarte inadequado destes resíduos na área de estudo pode resultar em contaminação por substâncias químicas do Aquífero Guarani e das águas superficiais.

Palavras-chave: Impacto Ambiental; Resíduos Farmacêuticos; Saúde Pública; Contaminação da Água.

Resumen

Los residuos de medicamentos se consideran un contaminante emergente que puede contaminar fuentes de agua y aguas subterráneas, además de ser un problema grave para la gestión de residuos en Brasil. El objetivo de este estudio fue evaluar el uso de medicamentos de uso humano y la forma en que la población desecha los medicamentos vencidos y en desuso. El estudio se realizó en dos barrios de Lages, bajo el Acuífero Guarani, en el sur de Brasil. En este estudio descriptivo y cuantitativo, la recolección de datos se realizó entre agosto y octubre de 2018 a través de un cuestionario respondido por 309 participantes. Las preguntas abordaron datos sociodemográficos, uso de medicamentos, destino de medicamentos vencidos y en desuso y sobre el saneamiento básico en el barrio. Las clases de fármacos más utilizadas fueron los antihipertensivos y los diuréticos, lo que indica una alta incidencia de enfermedades crónicas no transmisibles. Alrededor del 68% de los participantes dijeron que quedan restos de medicación después del tratamiento médico y el 70,2% que hay medicamentos caducados en casa. La eliminación de las sobras y los medicamentos vencidos se lleva a cabo en la basura doméstica, seguida de la eliminación en las aguas residuales domésticas. Solo un pequeño porcentaje (<15%) de los participantes desecha adecuadamente sus residuos de medicamentos. La disposición inadecuada de estos residuos en el área de estudio puede resultar en contaminación por sustancias químicas del Acuífero Guarani y de aguas superficiales.

Palabras clave: Impacto Ambiental; Residuos Farmacêuticos; Salud Pública; Contaminación del Agua.

1. Introduction

Drugs are essential to treat diseases and increase the life expectancy of the human population, however, disposing of unused and expired medicines is also essential for the maintenance of One Health, that representing the interrelationship between health human, animal and environmental health (Kaur & Singh, 2020). However, the most common method for disposal of expired and unused medications in households is disposal in household waste (as in Kuwait, UK, Lithuania, Qatar, Serbia, Ghana, Bangladesh, Malta and Saudi Arabia) or into the sewage system as still happens in some places of New Zealand, USA and Bangladesh (Kusturica et al., 2017). Only in Sweden and Germany, the most population have the habit of returning medicines to the pharmacy (Kusturica et al., 2017). Thus, according to the authors, the environmental impact of improper drug disposal is expected in countries with poorly functioning waste management. Furthermore, developing countries have limited financial resources to carry out the disposal of drug residues, when they have established official guidelines and protocols (Anwar et al., 2020).

Inappropriate drug disposal (leftovers, expired, and containers) can lead to several consequences such as accidental childhood poisoning, antibiotic resistance, negative impacts on wildlife, environment pollution and contaminate the surface and ground water due to its chemical composition and toxic properties (Falqueto et al., 2010; Bellan et al., 2012; Rogowska et al., 2019; Kaur & Singh, 2020). Pharmaceutical products are currently considered emerging contaminants for the environment, and some substances were found in Brazilian drinking water (Sodré et al., 2009; Locatelli et al., 2010; Montagner & Jardim, 2011).

Drug residues can enter the environmental through different routes. After use of medication by the population, the pharmaceutical components are totally or partially metabolized and excreted through urine or feces, reaching the collection system, and posteriorly the sewage treatment plant (Montagner & Jardim, 2011; Hess, 2018). After sewage treatment, the effluent liquid is commonly discarded in the environment (rivers, lakes, soil, outcrop areas) and the sludge is sent to the landfill or reused in agriculture. However, in Brazil, the current conventional sewage treatment system is not capable of totally breaking down pharmaceuticals, releasing them into the various environmental components (Montagner & Jardim, 2011; Hess, 2018). Other manners of contamination include the disposal of medications directly into the environment (into ditches, rivers, and soil), into the municipal waste collection system, as well as farms with intensive livestock that can directly contaminate the soil or aquatic systems, especially in rural areas where there are often no sewage treatment plants (Hess, 2018; Oliveira et al., 2019; Kaur &

Singh, 2020). Thus, in urban areas the main method of contamination of soil and superficial and subterranean waters is through human metabolites and medications in sewage or disposal in an inadequate location, while in rural areas it is through use and disposal of veterinary medications.

Within the pharmaceuticals, the antibiotics have been identified as a worrisome category of chemical contaminants. The growing quantity of antibiotics used by the population has generated discussions and concern among health professionals all over the world, due to its impact on health and the environment (WHO, 2019). Antibiotics are responsible for 12% of all ambulatory prescriptions, where more than half of the prescriptions are inadequate, and close to two-thirds of antibiotics are used without medical prescription (Wannmacher, 2004). The inadequate use and improper disposal of antibiotics is responsible for the contamination of water systems and for bacterial resistance acquired by some microorganisms (Petersen et al., 2009, Anwar et al., 2020; Kaur & Singh, 2020). As a result, many bacteria are already resistant to available antibiotics leading to increased morbidity and mortality for people, as well as an increased financial cost on the health system (Chang et al., 2015; Anwar et al., 2020).

In most Brazilian municipalities whose basic sanitation is still very precarious, the surface and subterranean waters are liable to contamination by infiltration of pharmaceutical products inadequately disposed of by the population. In the southern region of Brazil, only 44.9% of domestic effluents are destined for sewage treatment plants (SNIS, 2017). In the study area in Lages, southern Brazil, only 25.4% of the population has access to sewage treatment, and only 39.41% of the collected sewage is treated (SNIS, 2017). Furthermore, there is no data on the amount of health services waste collected in the municipality. Such data is worrisome, since the inadequate disposal of pharmaceuticals, considered chemical residues, associated with the inefficiency of basic sanitation can cause contamination of the Guarani/Serra Geral Aquifer system, which is a strategic reserve for the replenishment of water in Brazil. The referenced aquifer is considered the second largest reservoir of cross-border subterranean water in the world, both in territory and water volume, encompassing Brazil, Paraguay, Argentina, and Uruguay, and approximately 70% is on Brazilian territory (Curtarelli et al., 2010).

Knowledge on pharmaceuticals disposal in urban spaces is essential in order to propose preventative measures to reduce the number of chemical waste and water contamination (Kümmerer, 2009). Thus, the objective of this study was to evaluate the pharmaceutical consumption for human use and the disposal of unused and expired pharmaceuticals by residents of an urban outcrop area of the Guarani/Serra Geral Aquifer system, situated in a municipality in southern Brazil.

2. Methodology

This study was exploratory-descriptive and quantitative (Sampieri, 2013), conducted in the municipality of Lages, southern Brazil. The county's population is 157,743, and 98% of the residents live in the urban area (IBGE, 2018). In much of the Lages territory there is an outcrop of Botucatu sandstones and a matrix of the Guarani/Serra Geral Aquifer System.

In this study two neighborhoods were chosen located within the Guarani outcrop area. One location is the third largest neighborhood in the municipality in terms of territorial extension, and a large part of its territory is in the outcrop zone of the aforementioned aquifer, with 2,925 residences and 8,862 habitants (IBGE, 2010). However, even as the largest neighborhood in the municipality, it still presents precarious infrastructural and socio-economic conditions (IBGE, 2010). The second neighborhood chosen has an estimated population of 2,985, with 958 private permanent residences (IBGE, 2010). Both neighborhoods depend on the Basic Health Clinic to care for the local population, they possess solid residual collection and public distribution of water; however, they do not have a sewage collection network.

To determine the number of participants, the total number of private permanent residences were considered from both neighborhoods (3,883 homes.) A sample calculation was made to obtain the number of representative participants from the total number of residents, where only one person from each residence was included. Adapting a sample error of 10% and a confidence

level of 90%, the defined sample was a minimum of 255 participants (Nassar et al., 2018), but information was collected from 309 people.

The selection of individuals from the sample was by convenience (unsystematic). Participants were only included if they met the following criteria: had a fixed residence, were over 18 years of age, accepted participating in the study, and signed the informed consent form. Visitors that did not reside in the neighborhood and those younger than 18 years of age were excluded.

Information was collected using a questionnaire consisting of open and closed questions on socio-demographic data, use of medications, disposal of medications, and basic sanitation.

Data collection occurred between August and October of 2018. The participants were approached at their homes or at the Basic Health Clinic before their medical appointments. In the first instant, the objectives and methodology of the study were presented, followed by a reading of the informed consent. If participants agreed, they signed the informed consent and subsequently moved onto data collection that lasted roughly 20 minutes. The questions were read by the interviewer and answered by the interviewee.

The data were organized in an Excel spreadsheet and submitted to descriptive statistical procedures. Subsequently, the results were presented in figures and tables. In order to verify which variables were associated with the practices adopted for the disposal of medications, a chi-square test (X^2 test) was performed between the adequate and inadequate percentage of disposal and the variables gender, age, education level, and income. The study was approved by the Research Ethics Committee of the Planalto Catarinense University (no. 2.739.710).

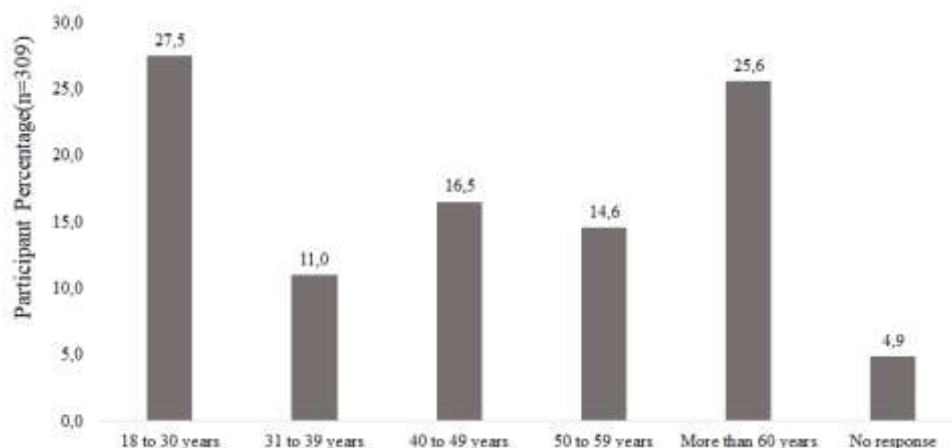
3. Results

The average age of participants was 45 years (SD19.2 years), and the highest percentage of people were between 18 and 30 years of age (27.5%), followed by those over 60 years (25.6%) (Figure 1). In addition, a high percentage of the sample (78.3%) was female, only 20.1% male, and 1.6% of the sample did not answer the question.

Regarding education, we found that most (28.2%) of the participants had incomplete elementary school, followed by those with complete high school (26.5%). In smaller percentages, there were respondents with higher education (4.5%) and only 1.3% of respondents with postgraduate studies. In terms of income, 35% of participants received up to R\$ 999,00, 18.1% of the participants reported no income, and a minority (2.9%) earned more than R\$ 3000,00.

Regarding the professional occupation of participants, we found that 28.5% of respondents did not report any profession, 21.4% reported being at home, 20.7% reported being retired. In lower percentages were the day laborers (7.8%), attendants (4.5%), self-employed and unemployed (3.2%), community health agents (2.9%), teachers (2.6%), students (1.9%), salespeople (1.6%), and 1.0% of participants reported having other professions.

Figure 1. Age percentage of residents in two neighborhoods in the city of Lages, Southern Brazil.



Source: Authors' production.

This study showed that 58.9% (182 people) reported using at least one pharmaceutical in the month prior to the survey. Among the most cited pharmaceutical, are antihypertensive medications, used by 51.1% of the participants (Table I). Analgesics were the second class of medications most used by individuals (30.2%). Lastly, diuretics, which are adjuvant medications in cases of hypertension (22.5%) and antidiabetic drugs (21.43%).

Regarding the percentage of individuals who check the shelf life of used drugs, 81.2% of respondents have this habit, however 16.8% do not check the expiration date of medications before consuming them. In addition, a high percentage of the sample (70.2%) never received information about the disposal of expired drugs, treatment leftovers, and packaging, while only 25.2% said they already received information, and another 4.5% did not answer the question.

Table 1. Percentage of drug classes consumed by participants residing in both neighborhoods in the city of Lages, Southern Brazil.

Substance Class	%
Anti-hypertensives	51,10
Analgesics	30,22
Diuretics	22,53
Antidiabetics	21,43
Anti-inflammatory	14,84
Antidepression	14,29
Antilipemic	13,19
Antiulcer	10,99
Anticonvulsant	10,44
Thyroid Hormones	10,44

* Only values greater than 10% were presented.
 Source: Authors' production.

In terms of pharmaceutical disposal, 65.4% of participants reported that there are medications left after medical treatment, only 31.7% of participants reported that there are no medications left and 2.9% did not the question. There was a high percentage of inadequate practices for the disposal of leftover medications, for example, 39.6% of participants discard in their

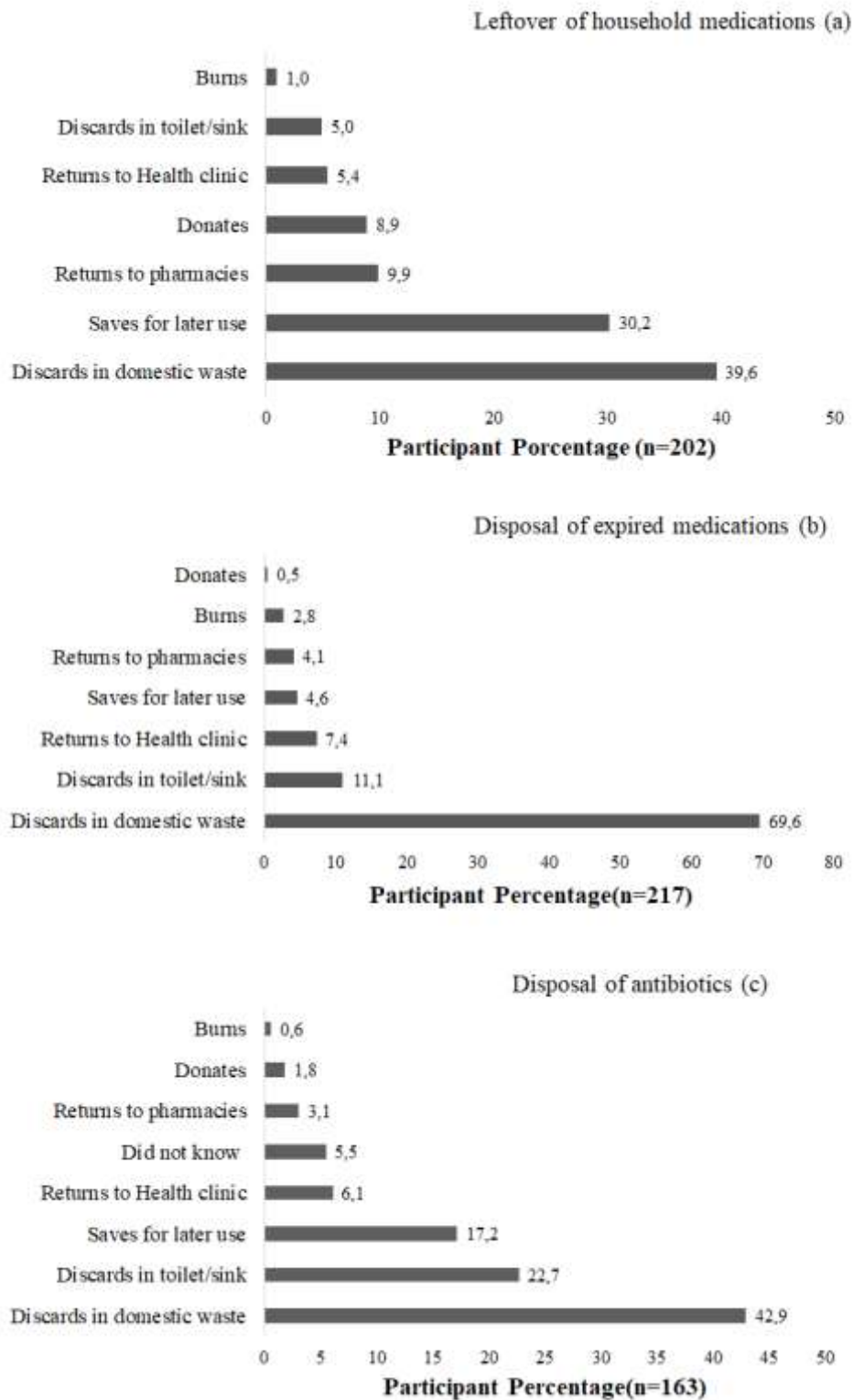
common household waste, and 30.2% save them to use on another occasion. On the other hand, only 15.3% of respondents dispose of them properly, turning the leftovers to the agency where it is sold or to the Basic Health Clinic (Figure 2a).

The sociodemographic data for age ($X^2 = 32.9$, $p \leq 0.000$) and educational level ($X^2 = 29.7$, $p = 0.003$) showed a significant association with the practices adopted for the disposal of leftover medication. The highest percentage of participants with incomplete elementary school and over 60 years of age reported that there is no leftover medication after health treatments. While the highest percentage of participants in the age group between 18 and 30 years, who have completed high school, incorrectly dispose of medications.

About 70% of the respondents reported having expired pharmaceuticals in their household, of these 69.6% discard in domestic waste, 11.1% discard them in the toilet and sink, 4.6% save them for use at another time. Only 4.1% said they returned the medication to the pharmacies, and 7.4% delivered the waste to the Basic Health Clinic (Figure 2b). Age ($X^2 = 28.5$, $p \leq 0.000$) and educational level ($X^2 = 22.2$, $p = 0.04$) of the participants showed a significant association with the practices adopted for the disposal of expired medications. The largest percentage of participants with incomplete elementary school and over 60 years of age reported that they do not have expired medications in their homes. Inadequate disposal of expired medications was associated with participants aged 18 to 30 years with incomplete elementary and high school education.

In terms of antibiotic waste, 32% of respondents reported no antibiotics left after treatment, 15.2% did not the question and 52.8% of participants reported that there are medications left after medical treatment. Of these, 42.9% said they discard in the domestic waste, 22.7% discard it in the toilet and sink and 17.2% save for it use at another time. Only 3.1% return the leftovers to the agency that sells them, and 6.1% take them to the Basic Health Clinic (Figure 2c).

Figure 2. Percentage of disposal methods of medication that is leftover (a), expired (b), and antibiotics (c) by residents in two neighborhoods in Lages, Southern Brazil.



Source: Authors' production.

In terms of participant’s knowledge on Reverse Logistics of expired or leftover medications, 88.7% of respondents reported being unaware, and 5.5% said they were aware (Table 2). Additionally, 43.7% of respondents are unaware of a location in Lages that receives medication waste, 29.8% responded that the health facility is the place to deliver the material, 12.9% responded pharmacies, and 13.9% did not answer the question.

When questioning whether participants knew about the Guarani Aquifer, 66.0% answered that they did not, 29.1% reported that they had some knowledge, and 4.9% did not answer the question (Table 2). The chi-square test showed a significant association between education and knowledge of the aquifer ($X^2 = 55.7$; $p \leq 0.000$). Those with knowledge of the Guarani Aquifer have complete or incomplete higher education.

Participants were asked if their neighborhood had inadequate medication disposal in general, 49.8% of respondents answered no, but 32.4% answered yes (Table 2). When questioned how sewage is treated in their homes, 47.2% of participants reported having a sewer, 34.6% reported having sewage collection system, 6.8% said sewage flows into the river, 6.5% did not respond, and 4.8% reported a rain collection network (Table 2).

Table 2. Percentage referring to the forms of sewage treatment in the participants homes of in the Santa Helena and Santa Monica neighborhoods, Lages, SC, Brazil.

	Yes		No		No response	
	n	%	n	%	n	%
Do you have knowledge about the Reverse Logistics of expired or leftover medication?	17	5.5	274	88.7	18	5.8
Does your household separate recyclables?	196	63.4	98	31.7	15	4.9
Do you know what is Guarani Aquifer?	90	29.1	204	66.0	15	4.9
Is there improper disposal of medications in your neighborhood?	100	32.4	154	49.8	55	17.8

Source: Authors’ production.

4. Discussion

The largest percentage of the sample was represented by women between the ages of 18 and 30 and elderly over 60 years. The predominance of females over males seems to be associated with the fact that a high percentage of women do not have occupations outside the home and were easily found in the Basic Health Clinic and residences, the locations where data collection took place. Moreover, individuals over 60 years old who are retired were at home or seeking medical treatment in the BHC due to the involvement of pathologies characteristic of the elderly.

Another aspect to be considered is the fact that women seek more medical care than men, and in general, are more concerned about their self-care and the health of their families, especially their children. In most cases, it is the mother who assumes the responsibility of doctor visits, hospitalizations, care, medication schedules, and other complications (Pereira et al., 2019). According to the author, the father, when present, finds it difficult to deal with the situation, preferring not to interfere with treatment or is absent when the child’s health condition seems severe. Additionally, the concept of being a masculine can make it difficult to practice self-care and search for a health service due to associations with weakness, fear, and insecurity bringing them closer to the female universe or shame in exposing their body to a health professional (Gomes et al., 2007; Pereira et al., 2019).

Regarding education, most participants reported having only incomplete elementary school, and consequently, the highest percentage of participants earned around minimum wage or reported having no income. These data reflect the socioeconomic condition of Lages, which is considered one of the regions with the lowest GDP per capita in the state of Santa Catarina. The city has a low (0.770) municipal human development index (MHDI), where only 66.9% of the population has a professional occupation, and the average monthly salary is 2.2 minimum wages (IBGE, 2010). The low occupational rate mentioned seems to be due to the scarce job opportunities, associated with the low number of companies located in the city, and the large rural area intended for cattle breeding that does not generate employment.

In Lages, a small number of farms occupy large tracts of land, while the majority of the population are workers, households, or small land owners (Locks, 2016). This historical fact, according to the author, may explain the reasons why the Santa Catarina mountain range still has the lowest human development index (HDI) of the state in many aspects such as housing, education, health, work, income, social protection, or infrastructure.

The data from the present study align with the pattern of medication use in the Brazilian population, where about 57.4% currently take medications and 41.7% report using one or two medications per day (Quadra et al., 2019). Moreover, according to the authors, 64% of respondents in nineteen Brazilian states have the habit of self-medicating, and 40.2% have experienced side effects, which have led to changes in treatment, resulting in leftover medications that can cause environmental contamination.

Use of medications varies according to age, gender, social, economic, and demographic elements (Carvalho et al., 2005, Souza et al., 2019). According to the National Survey on Access, Use, and Promotion of Rational Use of Medicines in Brazil, which collected data from 41,433 people between 2013 and 2014, the elderly, and those with chronic diseases, were the group with the highest rates of medication use (Bermudez & Barros, 2016). A cross-sectional epidemiological study conducted with women attending social groups for the elderly in the state of Santa Catarina, showed a prevalence of at least one medication in 98.7% of the sample, and 43.8% of elderly women were exposed to polypharmacotherapy (Souza et al., 2019). According to the authors, the high amount of medications consumed by the elderly is associated with the diagnosis of hypertension, diabetes mellitus, or osteoporosis.

In the present study, antihypertensive medications were the class of drugs most cited by participants, used by 51.1% of the population sampled in Lages. This data indicates that the main health problems of residents of both neighborhoods, seem to be associated with the occurrence of non-communicable chronic diseases (NCDs). This is made even more evident by the high use of diuretics, which are adjunctive medications in cases of hypertension.

Among NCDs, hypertension stands out as being largely responsible for the high number of patients. According to Tavares et al., (2016), in Brazil the prevalence of self-reported hypertension in the population is 23.7%, which ranges from 16.3% in the north to 26% in the southeast, where 59% of the elderly aged 60 years or older have the disease, while in the age group of 20 to 39 years the prevalence was only 6.0%.

According to the 2013 National Health Survey conducted by IBGE in partnership with the Ministry of Health in private households in Brazil, among the medications used to treat NCDs, it was observed that 80% were directed to treat hypertension, diabetes, and asthma. Moreover, in hypertensive patients, for example, the predominance of medication consumption was 82%, with more pronounced use in women and people over 75 years of age (Tavares et al., 2015). The same author showed that the Northern region had the lowest prevalence of diagnosis and medication treatment related to the NCDs investigated in the study, while in the Southeastern and Southern regions there was a higher prevalence of medication use to treat these diseases, probably due to greater access to health services and medical diagnosis. The present study showed that the drugs most used by participants in both neighborhoods were losartan and hydrochlorothiazide used for the treatment of hypertension, corroborating with the indicators in Brazil.

We also found that analgesics were the second class of medications most used by the individuals in the study (30.2%). Painkillers are commonly sold without a prescription in Brazil and abroad, and consequently have been found in natural waters worldwide (Heberer, 2002). The research performed with residents of Poland showed that almost 72% of the respondents indicated that analgesics were the group of pharmaceuticals most purchases (Rogowska et al., 2019). According to the Brazilian Pharmaceutical Industry Association, approximately 80 million Brazilians have a self-medication habit. The dispensing drugs without a prescription, associated with the low education level of individuals who use them, are the most relevant causes for the high rate of self-medication in Brazil (Carvalho et al., 2005), which probably explains the high percentage of people in the present study who reported leftover medications after treatment, and that they have expired medicines in their homes.

The data found in the present study, such as the high medication consumption by women and the elderly, the lack of verification of shelf life by a quarter of the sample population, and the high percentage of medication leftovers after treatment, suggest the need for studies on health risks. Moreover, studies on factors that explain the high consumption of medicines in the population that aim to support health education programs, as well as elaborate strategies to promote the rational use of medicines.

The expired/unused pharmaceutical are incorrectly disposed of in the aquifer outcrop areas in Lages, southern Brazil, especially in domestic waste. This result can be explained by the absence of a reverse logistics effective for medicines that predicts shared responsibility of the final destination, as well as actions aimed at environmental education of the population. Furthermore, a high percentage of participants (68%) reported that there are left over drugs from medical treatments, leading to assume that the population does not follow the prescription correctly, there are misconceptions in the doctor's prescription, free samples provided by manufacturers, and limitations to the purchase of medicines in the amount prescribed by doctors, which are all reasons that may cause accumulation of medicines in people's homes. Another likely explanation for the high amount of medication leftovers could be self-medication, prescription errors by health professionals and unfractionated sale of medications. The number of drugs that expire annually in Brazil is estimated at around 34,000 tons (ANVISA, 2013), and it is necessary to provide the environmentally appropriate final destination for such leftovers.

The data found in the sampled neighborhoods of Lages showed that the medication is disposed of in domestic waste and sewage for 44.6% of the treatment leftovers, and 80.7% for expired medicines, combining the two adopted practices (domestic waste and sewage). This result reflects the study by Quadra et al., (2019) who interviewed a sample of 540 people from different Brazilian states and showed that 66% of participants discard their expired and out-of-use medicines in the common waste, regardless of the participants' academic background. Similar results were also found by foreign researchers in Poland, where it was estimated that almost 68% of the respondents disposed of expired pharmaceutical in household waste or by flushing them down the toilet, and only 30% return to pharmacies (Rogowska et al., 2019).

In Brazil, Anvisa's RDC 222/18 recommends that medications, considered solid-state chemical waste generated by health care establishments, should be disposed of in hazardous waste landfill - Class I, and those in liquid state, need to be submitted to treatment prior to environmentally sound disposal, and to forbid such medications be sent to landfills (BRASIL, 2018). Only in 2020 the ordinance 10.388/2020 regulates the reverse logistics for medicines generated at home, handled and industrialized with the final consumer (BRASIL, 2020). This may explain the high percentage of participants in the present study who never received information about the disposal of medicines, the places that receive such residues and the reverse logistics system.

These figures seem to reflect the absence of an efficient Brazilian reverse logistics system for the population's medicines residue, in conjunction with the low investment in environmental education to inform the population. The national solid waste policy and resolutions as RDC 222/18 and 10.388/2020 regulates good health care waste management practices and encourages reverse logistics, which consists of a set of actions, procedures, and means for collection and restitution of solid waste to the business sector for reuse, or other environmentally sound disposal (BRASIL, 2018, 2020). According to these resolutions,

pharmacies and drugstores may receive expired and unusable drugs from the population. However, in practice, household medicines are still far from what reverse logistics proposes, thus is still no shared responsibility for environmentally appropriate disposal between manufacturers, importers, distributors, pharmacies and consumers.

The data raised in the present study are worrying, as improper disposal of medicines in the neighborhoods analyzed can contaminate the soil, surface and subterranean waters, such as the Guarani Aquifer, which has several outcrop areas with permeable rock, such as sandstone, in the urban area of Lages. Both neighborhoods do not have sewage collection and treatment, so the drugs disposed of in sinks and toilets can directly infiltrate the sandstone and contaminate the aquifer. On the other hand, when there is a sewage collection system, expired/ unused medicines, which are released directly to sinks and toilets, a common practice, reach the treatment plants in their original form, without undergoing metabolism changes in the human body, which can also contribute to environmental contamination (Carvalho et al., 2009).

Although the forms of release of pharmaceutically active compounds in the sewage collection system, and their presence in rivers located in populated regions are not fully known in Brazil, studies show their incomplete removal by the current sewage treatment system, which eventually launches these compounds into Brazilian surface waters (Colaço & Nascimento, 2014). For example, a study analyzing the Atibaia River water for residues of major antibiotics sold in Brazil found antibiotics such as amoxicillin, cephalexin, and norfloxacin (Locatelli et al., 2010). According to the authors, bacteria present in antibiotic contaminated environments may acquire resistance to these substances, since such organisms have genetic material with high mutation capacity. Another study identified the presence of different medications in the aquatic sediments of Bahia de Todos Santos, such as ibuprofen, hypertension medication, diclofenac, diazepam, carbamazepine, and erythromycin (Beretta et al., 2014).

The highest percentage of respondents are unaware of the basic sanitation situation in their neighborhood, as a high percentage (34.6%) reported that sewage is collected by the collection system, although both neighborhoods are devoid of a collection system. In addition, 11.7% of residents admitted discharging their sewage into the rainwater network or directly into the streams that run through the neighborhoods. Thus, in both neighborhoods the treatment system adopted in the residences is very precarious, where the sewage is discharged into rudimentary pits, rainwater, and rivers, whose contaminants may infiltrate the Botucatu sandstone and compromise the water quality of the Guarani Aquifer. In addition, the population's lack of knowledge of the existence, importance, and location of the Guarani Aquifer, is associated with low levels of education, which alerts the public authorities to the need for educational measures, aiming to raise awareness around the risk of contamination of urban rivers and groundwater, which represents a water reserve.

Additionally, we suggest including actions aimed at the disposal of household waste and expired medicines in the municipal waste management policy being prepared in Lages. Thus, the liability of pharmacies and drugstores in receiving expired drugs could be an alternative to minimize environmental contamination. Moreover, environmental education actions would be necessary to inform the population about the correct disposal, the risk of environmental and human contamination, as well as enabling the acceptance of leftover medicines within the validity period by the pharmacies of the public health system that could still be used in solitary pharmacies and encourage fractional sales.

Waste disposal due to health services, including home medicines, needs to be included as an agenda item in scientific research, in the political sphere, and in the academic education of health professionals (Alencar et al., 2014; Amarante et al., 2017). In addition, it is important to develop awareness of environmental preservation and to implement appropriate practices on health care waste management, including the leftovers of medicines generated in households, as well as involving the various entities of society, from the population to the manager.

5. Conclusion

Overall, this study showed that a high percentage of participants (58.9%) reported using at least one pharmaceutical in the month prior to the survey, as antihypertensive medications, analgesics, diuretics which are adjuvant medications in cases of hypertension and antidiabetic drugs. This data indicates that the main health problems of residents of both neighborhoods seem to be associated with the occurrence of non-communicable chronic diseases (NCDs). The expired and unused pharmaceutical are incorrectly disposed by the population, especially in the domestic waste and in the toilet can be an important source of contamination of the aquifer. These results can be explained by the absence of a reverse logistics effective for medicines and lack of knowledge of the population. Thus, it is essential to promote public policies related to the use and appropriate disposal of medicines and develop actions aimed at environmental education of the population about hazardous waste management and the importance of the Guarani aquifer.

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