Waterborne diseases classification and relationship with social-environmental factors in Florianópolis city – Southern Brazil

M. Cesa, G. Fongaro and C. R. M. Barardi

ABSTRACT

This study aimed to investigate and classify the occurrence of waterborne diseases in Florianópolis city, Santa Catarina State, Southern Brazil and to correlate these diseases with the following social-environmental indicators of the local population: type of water supply, adequate collection and sewage treatment, areas of flooding and domestic water tank cleaning. Reports of outpatients were analyzed for surveillance of waterborne diseases during the period of 2002 to 2009. Waterborne diseases were classified into four groups: Group A: diarrheal diseases; Group B: parasitological diseases; Group C: skin diseases and Group D: eye diseases. The diarrheal, parasitological and skin diseases were the most frequently reported. Waterborne diseases belonging to Group A in all sites were correlated with other waterborne diseases groups, which can be an indicator of the circulation of other waterborne diseases. Regarding the social-environmental indicators assessed, the most correlated with waterborne diseases were the origin and quality of the water supply, followed by inadequate collection and treatment of sewage, frequent flooding, and finally the lack of cleanliness of the water reservoir. The results highlight the need for policies aiming for improvement of the sanitation service in the maintenance of human, animal and environmental health.

Key words | human health, social-environmental indicators, waterborne diseases

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INTRODUCTION

According to Brazilian Institute of Geography and Statistics (Brazilian Institute of Geography and Statistics 2008), only 55.16% of the Brazilian municipalities have sewage collection network services. Regarding the wastewater treatment service, this number drops to 28.5% of Brazilian municipalities.

The city of Florianópolis (27 °S, 48 °W), is the capital of Santa Catarina State and, in recent decades, has shown a high population growth, mainly driven by migration; however, without adequate infrastructure to meet the needs of the population, regarding water quality and sewage treatment (Cesa & Duarte 2010). The city is composed of one main island, a continental part and surrounding small islands.

Florianópolis city is considered very important to the tourism industry because of the presence of scenic landscapes including more than 40 beaches. Florianópolis is considered one of the cities with best life quality in Brazil but, has only 44% coverage of sewage collection and treatment (Brazilian Institute of Geography and Statistics 2008).

During the summer period, the city receives a high influx of tourists that greatly increases the population number, multiplying also the load of sewage discharge in the water resources (Cesa & Duarte 2010).

So, these resources have been strongly affected by discharge of effluents from human activities, which compromises water quality and the health of people and animals. Contamination of water resources increases the risk of

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waterborne diseases transmission either by water intake and contact or by contaminated food intake (Fong & Lipp 2005).

Gastroenteritis, diarrhea, hepatitis, conjunctivitis and other clinical manifestations can be caused by waterborne pathogens, such as viruses, protozoa, helminthes and bacteria and are largely common diseases affecting low income countries. Some of these pathogens, especially enteric viruses, protozoa cysts and oocysts, are resistant to most water and sewage treatments and can remain viable for long periods in water and can survive in unfavorable environmental conditions normally lethal to other microorganisms (pH extremes, high temperature, salinity, ultraviolet radiation (UV)) (Hernroth *et al.* 2002; Horman *et al.* 2004; Li *et al.* 2010).

Despite awareness that the main waterborne diseases are not caused only by bacterial pathogens, in Brazil, as well as in many countries all over the world, the water quality is only evaluated according to bacteriological standards (Fong & Lipp 2005). Several studies indicate the greater liability of bacteria compared with other pathogens (Contreras-Coll *et al.* 2002; Husman *et al.* 2009). In Brazil, for example, enteric viruses, such as adenovirus (HAdV) and rotavirus A (RVA), are frequently detected in drinking water and the protozoa Cryptosporidium and Giardia are of major importance to public health authorities in developing and developed countries (Baldursson & Karanis 2011; Leal *et al.* 2013).

This study aimed to investigate and classify the waterborne diseases in Florianópolis city, Southern Brazil (SC), as well as to correlate these diseases with the following social-environmental indicators: type of water supply (distribution network of municipal utility or by alternative sources), presence of adequate collection and treatment of sewage, flooding frequency in the areas and performance of annual cleaning of the domestic water tank.

METHODOLOGY

Waterborne diseases surveillance

The surveillance of waterborne diseases was performed by the analysis of reports from outpatients during the period of 2002 to 2009. To perform the classification of waterborne diseases, four suburbs were selected in Florianópolis-SC: Saco Grande (Central), Barra da Lagoa (East), Costeira do Pirajubaé (North) and Armação do Pântano do Sul (South), since these regions geographically represent the most populated areas of Florianópolis city. These regions are exhibited in Figure 1.

A total of 38 Basic Units of Health (BUH) were selected, of which five were located in Saco Grande (Central) with 83,813 inhabitants, 11 in Barra da Lagoa (East) with 90,724 inhabitants, nine in Costeira do Pirajubaé (North) with 70,207 inhabitants and 11 in Armação do Pântano do Sul (South) with 90,997 inhabitants. The number of affected people per 1,000 inhabitants (NAP/1,000 inhabitants) was evaluated.

Classification, prevalence and correlation study of the waterborne diseases in Florianópolis-SC and social-environmental conditions

Waterborne diseases were classified into four groups: Group A: diarrheal diseases; Group B: parasitological diseases; Group C: skin diseases; Group D: eye diseases, considering

Figure 1 | Location of the study areas in Florianópolis, Santa Catarina State, Southern Brazil.

that these are the waterborne diseases most frequently reported in the world (World Health Organization (WHO) & UNICEF 2009), using the classification of Heller (1997).

The prevalence map of the waterborne diseases was generated, including distribution and classification of the diseases in Florianópolis regions using Quantum GIS software (free and open source geographic information system).

To assess the correlation between socio-environmental conditions and waterborne diseases, 695 households were consulted, using questionnaires, covering 6% of the population of each site. Population groups were classified as: Group (1) type of water supply (distribution network of municipal utility or by alternative sources, such as Collective Systems of water supply and spring source water); Group (2) presence of adequate collection and treatment of sewage; Group (3) flooding frequency in the areas; and Group (4) performance of annual cleaning of the domestic water tank.

Pearson Correlation Test GraphPad Prism 5.0 – USA, was applied using the correlation coefficient (r^2). The values were considered significant when $p \leq 0.05$, to statistically evaluate the vulnerability to waterborne diseases occurrence according to social-environmental condition and to evaluate the correlation between waterborne diseases groups themselves.

The average of waterborne diseases prevalence for each group was calculated and analysis of variance (ANOVA, single factor), GraphPad Prism 5.0 – EUA, was used to determine the statistical significance of the data. Values were considered significant when $p \leq 0.05$.

RESULTS

Prevalence, classification, correlations and geographic distribution of waterborne diseases in Florianópolis city (SC)

Table 1 shows the prevalence of waterborne diseases during the period of the study (2002 to 2009) in the Center, East, South and North of Florianópolis city. Using these data it was possible to draw up a map of distribution and prevalence of the waterborne diseases (Figure 2).

The results of the waterborne diseases classification in Group A (diarrheal diseases), Group B (parasitological diseases), Group C (skin diseases) and Group D (eye diseases), and their respective prevalence in Florianópolis are shown in Figure 3.

Saco Grande suburb showed an exponential trend of increase from 2004 to 2009 in waterborne diseases belonging to Groups A ($r^2 = 0.8$), C ($r^2 = 0.6$) and D ($r^2 = 0.7$) and a linear decay in the waterborne diseases belonging to Group B ($r^2 = 0.7$).

In Barra da Lagoa suburb, waterborne diseases belonging to Group A showed an exponential trend of increase during 2003 to 2006 ($r^2 = 0.8$) and a decay during 2006 to 2009 ($r^2 = 0.7$), waterborne diseases belonging to Group B showed a linear decay during 2005 to 2007 ($r^2 = 0.8$), and waterborne diseases belonging to Group C showed a linear increase during 2002 to 2005 ($r^2 = 0.7$) and a linear decay during 2006 to 2009 ($r^2 = 0.8$).

In Costeira do Pirajubaé suburb, waterborne diseases belonging to Group A showed a linear increase during 2006 to 2008 ($r^2 = 0.8$) and a linear trend of decay after this period ($r^2 = 0.7$), waterborne diseases belonging to Group B showed an exponential decay during 2002 to 2007 ($r^2 = 0.6$) and after this period, a linear increase ($r^2 = 0.8$), waterborne diseases belonging to Group C showed a linear decay during 2006 to 2009 ($r^2 = 0.7$), and waterborne diseases belonging to Group D showed a linear decay during 2002 to 2004 ($r^2 = 0.8$) and, after this period, a stabilization was observed.

In Armação do Pântano do Sul suburb, waterborne diseases belonging to Group A showed an exponential increase during 2002 to 2006 ($r^2 = 0.8$), waterborne diseases belonging to Group B and C showed exponential decay during 2002 to 2009 ($r^2 = 0.7$ and 0.8, respectively) and waterborne diseases belonging to Group D showed exponential increase during 2004 to 2006 ($r^2 = 0.8$) and an exponential decay after 2006 ($r^2 = 0.8$).

Positive correlations were observed between waterborne diseases belonging to groups 'A, B, C and D' per suburb evaluated, showing the following profile (Figure 4): (1) In Saco Grande the Group A waterborne diseases were correlated with Groups B ($r^2 = 0.8$) and C ($r^2 = 0.9$), Group B waterborne diseases were correlated with Group C ($r^2 = 0.8$) and Group C waterborne diseases were correlated with

Table 1 | Prevalence of waterborne diseases from 2002 to 2009 in Center, East, South and North of Florianópolis city (number calculated per 1,000 inhabitants)

		Year								
Site	**Basic units of health**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Average**
Center	Trindade	ND	ND	6.9	30.7	31.5	30.5	35.0	34.0	28.1
	Agronômica	73.3	52.9	42.3	28.7	39.1	32.5	31.9	45.1	43.2
	Prainha	88.8	68.2	50.3	99.4	83.8	63.8	89.0	79.5	77.8
	Monte Serrat	42.7	50.5	52.2	53.6	40.3	57.4	40.3	22.5	44.9
	Policlínica Centro	13.8	11.3	8.6	5.6	4.9	4.1	9.6	6.4	8.0
	Total	54.7	45.7	32.1	43.6	39.9	37.7	41.2	37.5	41.5
East	Saco Grande	65.7	66.5	69.9	68.7	97.2	104.2	88.8	118.9	85.0
	João Paulo	30.2	19.3	23.6	20.7	34.6	28.2	36.0	39.3	29.0
	Itacorubi	35.3	37.2	34.2	35.4	28.7	28.4	46.8	22.0	33.5
	Córrego Grande	13.1	24.1	15.0	15.9	14.2	10.6	13.5	23.7	16.3
	Pantanal	46.1	0.0	25.0	32.7	34.4	16.8	36.9	32.8	28.1
	Lagoa da Conceição	78.6	77.8	74.3	68.3	79.7	86.9	69.6	65.9	75.1
	Costa da Lagoa	70.9	87.5	63.3	71.8	125.0	123.4	181.2	118.8	105.2
	Canto da Lagoa	17.5	22.8	38.8	39.6	61.0	45.9	48.3	30.0	38.0
	Barra da Lagoa	39.6	29.8	38.2	59.4	89.5	41.5	31.7	15.0	43.1
	Total	44.1	40.6	42.5	45.8	62.7	54.0	61.4	51.8	56.7
North	Ingleses	24.9	20.0	28.1	21.8	13.0	13.2	22.6	18.0	20.2
	São João do Rio Vermelho	53.6	61.9	50.0	43.5	45.3	36.6	30.2	34.9	44.5
	Vargem Grande	129.0	53.4	56.3	82.8	67.7	23.0	27.4	18.6	57.3
	Cachoeira do Bom Jesus	105.2	112.7	53.7	40.9	45.3	33.0	33.8	24.9	56.2
	Ponta das Canas	55.8	57.5	42.3	44.1	37.7	21.3	33.3	29.7	40.2
	Santo Antonio de Lisboa	75.8	93.0	56.8	39.1	47.5	33.0	30.6	21.9	49.7
	Ratones	149.8	201.5	155.1	126.5	86.7	56.5	30.2	11.5	102.2
	Jurerê	52.3	60.1	35.5	53.8	49.7	28.3	24.5	20.3	40.6
	Vargem Pequena	48.2	95.1	50.9	48.9	23.2	31.7	24.2	14.7	42.1
	Canasvieiras	13.0	16.6	64.2	67.2	38.1	17.8	18.4	13.3	31.1
	Total	70.8	77.2	59.3	56.9	45.4	29.5	27.5	20.8	38.8
South	Rio Tavares	42.2	54.3	36.2	47.4	59.8	49.6	42.9	26.4	44.9
	Campeche	38.1	35.5	40.1	47.5	90.0	34.4	35.1	15.1	42.0
	Morro das Pedras	73.8	72.2	64.5	39.0	43.8	30.0	51.7	31.2	50.8
	Faz. Rio Tavares	78.7	75.3	105.6	83.9	59.7	89.1	66.4	21.4	72.5
	Cost. do Pirajubaé	74.2	70.6	50.3	54.3	54.4	39.7	53.0	29.2	53.2
	Arm. Pânt. do Sul	129.2	122.5	140.8	158.1	175.2	116.0	102.2	69.4	126.7
	Pântano do Sul	78.7	105.0	131.9	98.9	114.5	67.4	54.2	65.1	89.5
	Saco dos Limões	23.6	20.8	22.6	28.5	26.5	27.0	36.1	30.9	27.0
	Tapera da Base	43.7	71.2	57.4	68.1	48.8	47.6	61.3	58.7	57.1
	Ribeirão da Ilha	97.2	65.8	60.0	40.7	49.5	28.2	26.8	92.1	57.5
	Carianos	24.5	26.7	17.5	34.7	55.7	61.3	65.3	65.5	43.9
	Alto Ribeirão	50.9	40.3	34.1	29.3	60.0	65.5	37.8	51.4	46.2
	Cai. da Barra do Sul	4.5	22.1	0.0	195.1	85.0	73.4	62.2	94.6	67.1
	Total	58.4	60.2	58.5	71.2	71.0	56.1	53.4	50.1	59.9

Group D (r^2=0.9); (2) In Barra da Lagoa the Group A waterborne diseases were correlated with Groups B ($r^2 = 0.9$), C ($r^2 = 0.7$) and D ($r^2 = 0.9$), and Group C with B ($r^2 = 0.8$); (3) In Costeira do Pirajubaé the Group A waterborne diseases were correlated with Group C ($r^2 = 0.9$); Group C waterborne diseases were correlated with Group D ($r^2 = 0.7$) and Group D waterborne diseases were correlated with Group B ($r^2 = 0.8$); (4) In Armação do Pântano do Sul, the Group A waterborne diseases were correlated with Group C ($r^2 = 0.8$) and the Group C waterborne diseases with Group B ($r^2 = 0.7$). The values were considered significant when $p \leq 0.05$.

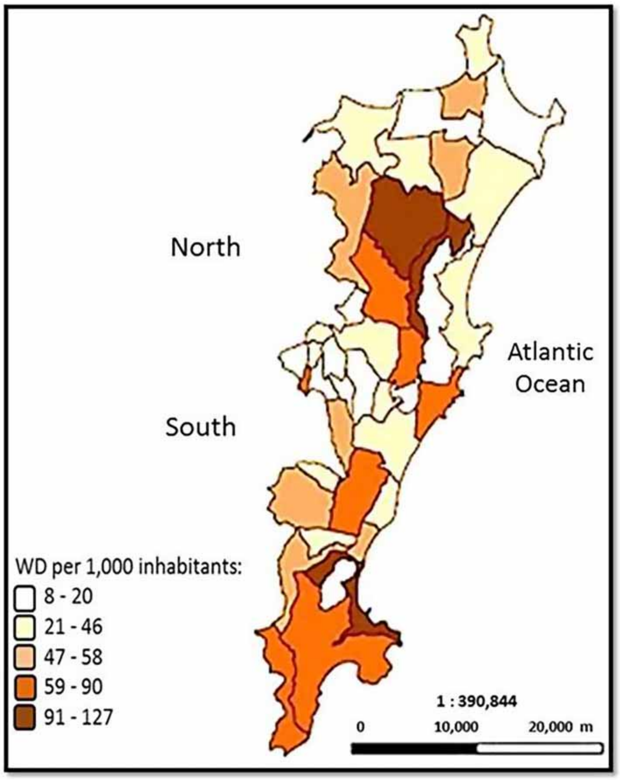

Figure 2 | Mapping of the distribution and prevalence of waterborne diseases in Florianópolis-SC.

The global analyses of all waterborne diseases groups in all evaluated regions of Florianópolis, allowed us to establish the following positive correlation of the waterborne diseases: Group A with Group B, C and D ($r^2 = 0.8$, 0.9 and 0.8, respectively); Group B with Group C ($r^2 = 0.8$) and Group C with Group D ($r^2 = 0.8$).

Correlation study between waterborne diseases and social-environmental conditions

According to waterborne diseases prevalence and classification in the four suburbs studied, it was possible to establish a correlation between waterborne diseases and social-environmental conditions of the population.

The results of the impact of social-environmental conditions are shown in Table 2. According to Hinkle *et al.* (1988), the $r^2 \geq 0.85$ was considered high correlation, $r^2 = 0.65$ to 0.84 was considered medium correlation, $r^2 = 0.45$ to 0.63 was considered moderate correlation, and $r^2 = 0.25$ to 0.44 represented low correlation. The values were considered significant when $p \leq 0.05$.

Regarding the social-environmental characteristics recorded, the following ranking was designed, based on the r^2 value of the general waterborne diseases (shown in Table 2): (i) water supply from Collective Systems; (ii) inadequate collection and treatment of sewage; (iii) frequent flooding; (iv) lack of annual cleaning of the domestic water tank.

As the water supply source and sewage collection services were more correlated with the waterborne diseases, a specific analysis was conducted based on the classification of waterborne diseases according to type of water supply and quality of the sewage collection service. To do that, the total population was classified as: Population (1) Water from Collective Systems; Population (2) Water from Network – Municipal Utility; Population (3) Less than 50% of houses attended by sewage collection and treatment; Population (4) At least 50% of houses attended by sewage collection and treatment service.

The results showed that the population supplied with water from Collective Systems and who had less than 50% of the sewage treatment and collection were the most affected by waterborne diseases (Figure 5), considering the significant increase of waterborne diseases in this population (ANOVA analysis, $p \leq 0.05$).

DISCUSSION

Waterborne diseases are caused by a wide range of pathogens, including bacteria, viruses and protozoa. However rotavirus is the leading cause of acute diarrhea, and is responsible for about 40% of all hospital admissions due to diarrhea among children under five years old, worldwide. Bacterial pathogens, such as *Escherichia coli*, *Shigella* ssp., *Campylobacter* ssp. and *Salmonella* ssp., and the protozoan pathogen, Cryptosporidium have also been frequently isolated (World Health Organization (WHO) & UNICEF 2009).

The most important hospitalization cases due to waterborne diseases in Santa Catarina State (Brazil) according to the Oswaldo Cruz Foundation (Fundação Oswaldo Cruz; Fiocruz 2010), during 2002 to 2009, were caused by the development of hepatitis 'A' (ranging from 4.3 to 15.4

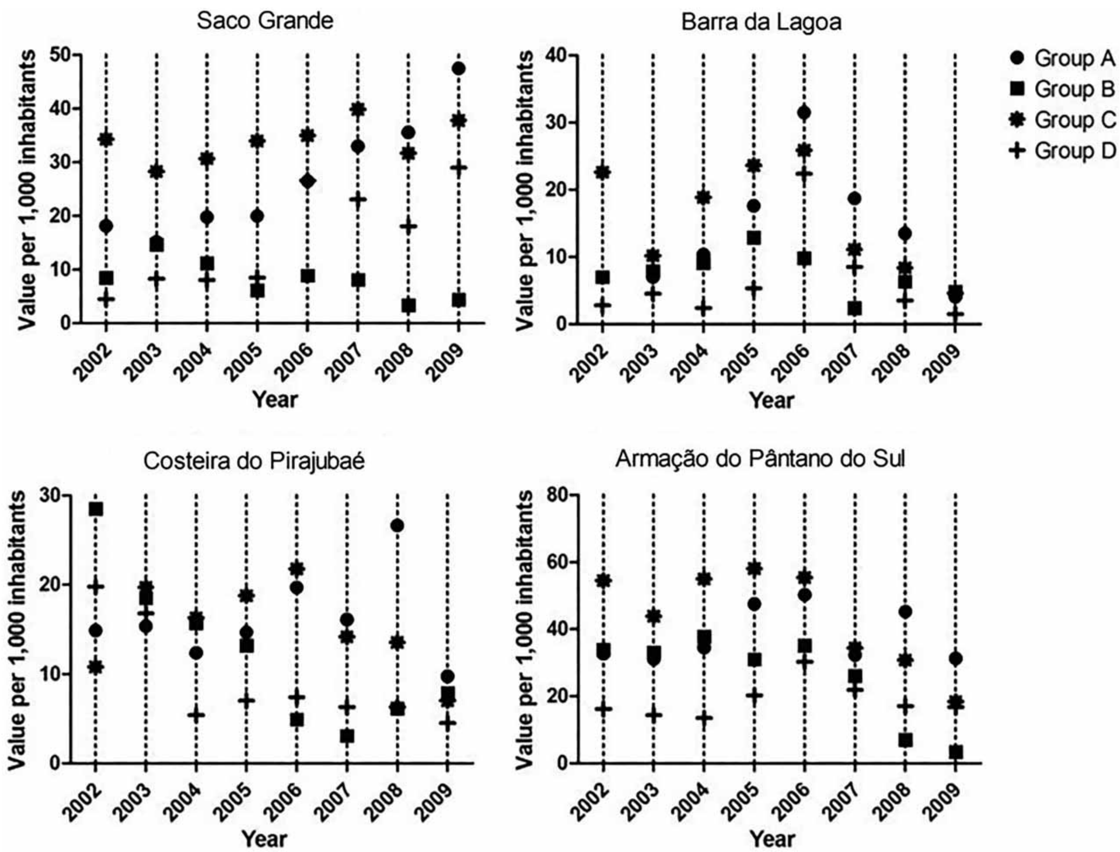

Figure 3 | Waterborne diseases classification and prevalence in Florianópolis city (SC) from 2002 to 2009.

cases per 100,000 inhabitants), leptospirosis (ranging from 3.4 to 15 cases per 100,000 inhabitants), amebiasis (ranging from 0.1 to 1.9 cases per 100,000 inhabitants), typhoid fever (ranging from 0.1 to 0.15 cases per 100,000 inhabitants) and esquistosomosis (0.1 cases per 100,000 inhabitants). Moresco *et al.* (2012) reported 51% of positivity hepatitis A (genome) in recreational water in Florianópolis-SC.

However, it is rare that studies aim to correlate waterborne diseases with the etiologic pathogen, social, geographic and environmental distribution and with other factors in low income countries, such as Brazil (Figueras & Borrego 2010). According to the results obtained on positive correlation analyses, the waterborne diseases belonging to Group A (diarrhea) in all sites were correlated with other groups of waterborne diseases. This fact is important, because the occurrence of a waterborne disease belonging to Group A can be indicator of the circulation of other waterborne diseases.

The results suggest that correlation of Group A with the other groups of waterborne diseases is mainly due to contamination of water by human sewage, since most of the waterborne diseases are caused by pathogens that are excreted and disseminated by human feces. Discharge of effluents from human activities compromises water quality and consequently the health of people and animals, since many waterborne pathogens such as enteric viruses, bacteria, protozoa cysts and oocysts are excreted in feces in high amounts (Fong & Lipp 2005; Leal *et al.* 2013).

Group A (diarrhea) waterborne disease is the second leading cause of death in children under five years old, and is responsible for the death of around 760,000 children every year, and can be caused by a variety of bacterial, viral and parasitic organisms (World Health Organization (WHO) & UNICEF 2010). In Santa Catarina State (Brazil), the Group A waterborne disease was also a remarkable cause of mortality in children, during the years of 2002 to

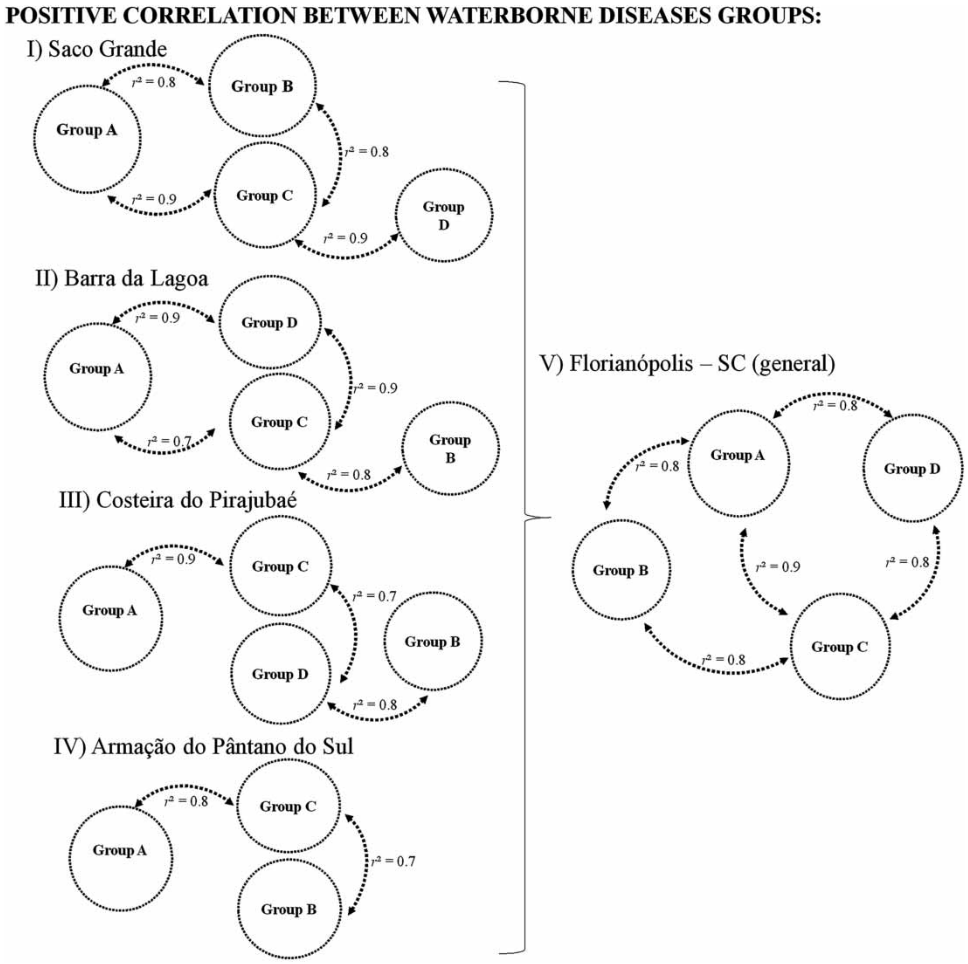

Figure 4 | Correlations among waterborne diseases Group A: Diarrheal Diseases (A); Group B: Parasitological Diseases (B); Group C: Skin Diseases (C); Group D: Eye Diseases (D) in Saco Grande (I), Barra da Lagoa (II), Costeira do Pirajubaé (III), Armação do Pântano do Sul (IV) and in Florianópolis city (considering all evaluated sites). The $r^2 \geq 0.85$ was considered high correlation, $r^2 = 0.65$ to 0.84 was considered medium correlation, $r^2 = 0.45$ to 0.63 was considered moderate correlation, and $r^2 = 0.25$ to 0.44 represented low correlation. The values were considered significant when $p \leq 0.0$.

2009 when it was registered at a rate ranging from 0.1 to 1.2 deaths per 100,000 inhabitants (Fundação Oswaldo Cruz; Fiocruz 2010).

The parasitological diseases (Group B), are among the most common worldwide and affect the poorest and most deprived communities, and the helminthes can be transmitted by contaminated feces, water and soil, where sanitation is poor (World Health Organization (WHO) & UNICEF 2009).

Skin diseases (Group C) caused by contaminated water are very frequent and underestimated (Brazilian Society of Dermatology 2006). The information regarding these diseases is of great importance for targeting appropriate public policies (Chiacchio *et al.* 2014).

Oscillations in the annual frequency of waterborne diseases are frequently observed. Factors such as climatic conditions, social practices, increasingly frequent displacements, habits of hygiene and water supply quality are factors that can contribute to waterborne disease variations and correlations (Aquino *et al.* 2007; Chiacchio *et al.* 2014).

It is globally accepted that sanitation and clean water are essential to life, dignity and human development (World Health Organization (WHO) & UNICEF 2013). Importantly a significant fraction of the population may have a level of immunity to infection by waterborne pathogens, which does not result in disease. The contact with a pathogen can vary from asymptomatic infection to death,

Table 2 | Correlation study between waterborne diseases and social-environmental conditions of the population

Social-environmental conditions	Group A	Group B	Group C	Group D	General WDs
	r^2 values				
Water supply from Collective Systems	0.73	0.64	0.89	0.66	0.86
Inadequate collection and treatment of sewage	0.87	0.42	0.85	0.43	0.83
Frequency of flooding	0.89	0.38	0.74	0.41	0.63
Not performed annual cleaning of the domestic water tank	0.66	0.39	0.61	0.42	0.61

$r^2 \geq 0.85$ was considered high correlation, $r^2 = 0.65$ to 0.84 was considered medium correlation, $r^2 = 0.45$ to 0.63 was considered moderate correlation, and $r^2 = 0.25$ to 0.44 represented low correlation. The values were considered significant when $p \leq 0.05$.

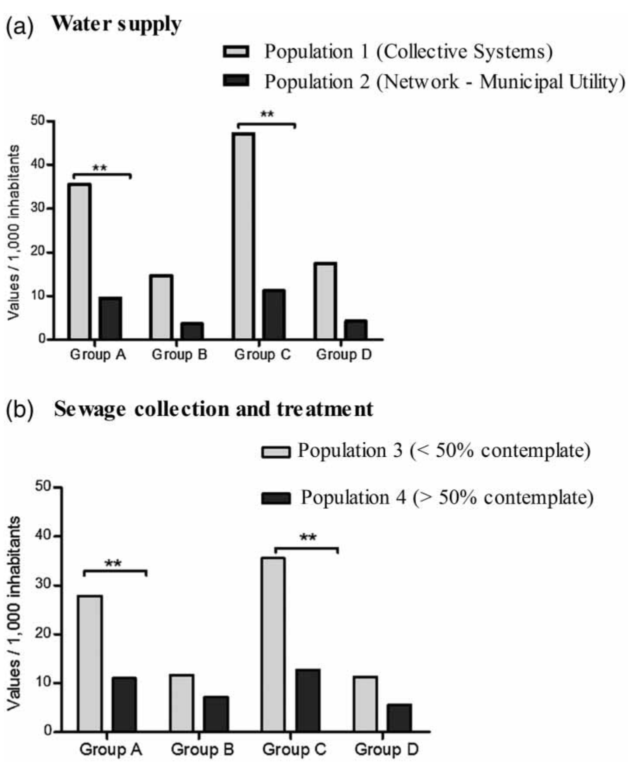

Figure 5 | Classification of the waterborne diseases in Group A: Diarrheal Diseases (A); Group B: Parasitological Diseases (B); Group C: Skin Diseases (C); and Group D: Eye Diseases (D), according to water supply source and sewage collection. **: significant difference among the groups (ANOVA analysis, $p \leq 0.05$).

since it depends on the immune conditions of the host and also the infectivity and virulence degree of the pathogenic agent (Gerba *et al.* 2002).

The distribution of chlorinated water contributed significantly to the reduction of waterborne diseases, but the water distribution system may receive contaminant agents, since it is already described that biofilm formation can increase the resistance of micro-organisms to chlorine treatment (Szewzyk *et al.* 2000; Keevil 2003; Thurston-Enriquez *et al.* 2003).

It is reported that bacterial biofilms, often present in pipes, can add other micro-organisms, such as viruses, playing a role of accumulation, protection and dissemination of pathogens in drinking water networks (Stewart *et al.* 2001; Helmi *et al.* 2008).

The results presented in this manuscript reinforce the urgency to intensify the studies and application of public policies to improve the quality of basic sanitation. Public policies must notify the presence and frequency of outbreaks, promoting the control of transmission of pathogens by water through the treatment of urban sewage and drinking water, which will impact positively on the quality of recreational water, water for food production and human consumption and consequently improve human health (Gerba *et al.* 2002; World Health Organization (WHO) & UNICEF 2013).

CONCLUSIONS

Diarrheal (Group A), parasitological (Group B) and skin diseases (Group C) were the waterborne diseases most frequently reported in Florianópolis-SC. Waterborne diseases belonging to Group A were correlated with all the other waterborne diseases groups evaluated, which can be a potential indicator both of the circulation of waterborne diseases and also of the social-environment factors, water supply quality and sanitation. There is an urgency to intensify attention to human, animal and environmental health, as well as to discuss containment plans to control, prevent and properly diagnose these diseases.

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