SALUD COLECTIVA, Buenos Aires, 9(1):53-63, January - April,2013

The origin and quality of water for human consumption: the health of the population residing in the Matanza-Riachuelo river basin area in Greater Buenos Aires

Origen y calidad del agua para consumo humano: salud de la población residente en el área de la cuenca Matanza-Riachuelo del Gran Buenos Aires

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ABSTRACT The aim of this study is to analyze the origin and quality of water used for consumption in a sample of households in Matanza-Riachuelo river basin area in Greater Buenos Aires, Argentina. The results of drinking water by source indicated that 9% of water samples from the public water system, 45% of bottled water samples and 80% of well water samples were not safe for drinking due to excess content of coliforms, *Escherichia coli* or nitrates. Individuals living in households where well water is the main source of drinking water have a 55% higher chance of suffering a water-borne disease; in the cases of diarrheas, the probability is 87% higher and in the case of dermatitis, 160% higher. The water for human consumption in this region should be provided by centralized sources that assure control over the quality of the water.
KEY WORDS Environment; Water Quality; Waterborne Diseases; Argentina.

RESUMEN El objetivo del estudio es analizar el origen y la calidad del agua domiciliaria utilizada para el consumo, en una muestra de hogares del área de la cuenca Matanza-Riachuelo del Gran Buenos Aires, Argentina. Según su origen, el 9% de las muestras de agua provenientes de la red pública, el 45% de las de agua envasada y el 80% de las provenientes de perforaciones o pozos individuales resultaron no potables por exceso de coliformes, *Escherichia coli* o nitratos. Los individuos de la muestra de hogares en los que la fuente principal de agua para el consumo eran pozos individuales presentaron una probabilidad 55% superior de padecer alguna enfermedad de origen hídrico, probabilidad que llegaría al 87% en el caso de las diarreas y al 160% en el de las dermatitis. El agua para consumo humano en este territorio debería provenir de fuentes centralizadas que aseguren el control de la calidad del agua.
PALABRAS CLAVES Ambiente; Calidad del Agua; Enfermedades Transmitidas por el Agua; Argentina.

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INTRODUCTION

The ways in which the marginal areas of cities develop, without taking into account the constraints of the natural environment or infrastructure needs, generate a series of social and environmental problems. These problems are derived from the lack of drinking water, flooding, and inadequate hygiene conditions due to lack of sanitation facilities, overcrowding, and lack of urban planning that prevents everything from public street cleaning to the entrance of ambulances, all of which exposes the population to a contaminated environment (1). Greater Buenos Aires (a), one of the most densely populated areas of Argentina, holds 30% of the total population of the country – more than 12 million people, according to the 2010 National Population and Housing Census in Argentina (2) – and is one of the 12 largest urban agglomerations in the world (3). It is an example of unplanned population growth, with significant deficits in basic sanitation services and the existence of numerous environmental risk factors to which its inhabitants are exposed.

According to the estimates by Cravino *et al*. (4), population growth in the settlements and shantytowns of the 24 counties of the province of Buenos Aires (which are part of Greater Buenos Aires) has been considerable and shows an increasing trend in recent years. The population growth in this type of informal settlements during the period 1981-2001 was 63% in the county of Merlo and 86% in the county of Moreno, while in Almirante Brown, Esteban Echeverría and Lomas de Zamora growth reached 1,800%, 666% and 228% respectively (mentioning only the most dramatic changes). The same study shows that the population living in informal settlements has grown much faster than the total population. Between 1981 and 2006, the population in slums and settlements grew, in relative terms, by 220% compared to a 35% population growth in Greater Buenos Aires. It is estimated that, in the five years between the 2001 census and 2006, for every 100 new residents in the 24 counties of Greater Buenos Aires, 60 moved into informal settlements and 40 into the "formal" city; in the period 1981-1991, the proportion of the population that moved into informal settlements was 10 in 100, and in the period between 1991 and 2001 it was 26 in 100 (4).

Lvovsky (5) estimates that about 5.5% of the disability-adjusted life years lost in Latin America and the Caribbean originate from sanitation services deficiencies, compared with the 1% in industrialized countries.

The World Health Organization states that the lack of safe water, health services and hygiene is, globally, the most important environmental risk factor in terms of disability-adjusted life years and the second most important risk factor in terms of deaths (6).

An assessment of the impacts that the provision of sanitation services would have indicates that, if access to services were universal, the global number of diarrhea episodes would be reduced, on average, by 16.7%. If water purification in places of consumption were added, the reduction of episodes would reach 53% on average. Finally, providing access to a regulated running water supply, household connection to the sewage system and partial treatment of sewage would achieve an average reduction of 69% (7).

According to the data from the population census of 2010 (2), the service coverage of the public water and sewage systems in the 24 counties of Greater Buenos Aires is quite heterogeneous, with households with access to the public water network ranging from 10% (in Malvinas Argentinas) to 100% (in Vicente López) (b), and access to the sewage system ranging from 2% (in Malvinas Argentinas) to 97% (in Vicente López). According to the same source, the average coverage of the public water system in all of the Province of Buenos Aires is 75%, whereas the sewage system does not even serve half of all households (48%). These figures contrast sharply with the coverage levels in the Autonomous City of Buenos Aires, where 100% and 98% of households have access to each of the services, respectively.

The results of a recent study on the counties of Greater Buenos Aires suggest that the lack of basic sanitation services has a strong impact on the probability of suffering from diarrhea, as well as showing the existence of a significant synergistic effect among the lack of sanitation services, the educational level of the head of the household and the proximity to dumps that substantially increases the risk of suffering from the disease (8).

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The aim of this study is to deepen the analysis of the relationship between the deficit of sanitation services (or the deficiency in their quality) and the contracting of waterborne diseases among the population residing in the area of the Matanza-Riachuelo river basin (c) (belonging to Greater Buenos Aires). For this purpose, the origin and quality of water used for consumption was examined in a sample of households from the study area where a waterborne disease had been detected, and the correlation of the results with the presence of each of the diseases under study was analyzed.

METHODS

In order to study to what extent the poor quality of water used in households could be the mechanism that increases the risk of suffering from waterborne diseases among the population without access to water from the public water network, water samples were collected in 90 households inhabited by 380 people located in the Matanza-Riachuelo river basin between October 2010 and February 2011.

The master sample consisted of 151 households in which cases of individuals suffering from waterborne diseases in the last year (through a health self-report) had been detected by means of a survey conducted between May and September 2010 in the counties of the Matanza-Riachuelo river basin. The survey was based on a random, two-stage stratified sample design within the Matanza-Riachuelo river basin territory. The sampling units of the first stage were census tracts [*radios censales*] and the sampling units of the second stage were households. The three stratification criteria (in the first stage) were: 1) state of access to the public water and sewage networks 2) location in flood or non-flood zones, and 3) a synthetic indicator of population vulnerability (in this case, the indicator used was unmet basic needs). Forty census tracts were randomly selected within each stratum and 20 surveys were conducted in each tract (via random selection of households).

In order to minimize problems regarding the seasonality of waterborne diseases, the period of reference for questions about these diseases was the last twelve months.

The final sample for the 2011 survey was composed of those households belonging to the master sample in which waterborne diseases were reported in the last year and with whom it was possible to arrange an appointment (130 households). Of these households, 90 received the field staff (the person in charge of taking the water sample and the person in charge of administering the supplementary questionnaire). The most frequent reason for the rejection of the field researchers expressed by the households was associated with safety issues (even in the cases where the interview had been arranged by telephone). However, the cases of non-response did not follow a geographic pattern nor were they related to the household characteristics.

Water samples were obtained from households of the counties of Almirante Brown, Avellaneda, Cañuelas, Esteban Echeverría, La Matanza, Lanús, Lomas de Zamora, Marcos Paz and the Autonomous City of Buenos Aires, in areas served by centralized services (the public water network) or individual services (wells or boreholes).

The samples were collected from the tap used for the provision of water for household consumption, whether fed directly from the source or from the household water storage system (tank or cistern). In addition, the benefits of collecting additional samples in those cases where there were doubts about the sanitation of the water tank were assessed. In such cases, the staff sought to collect the additional sample from the connection to the source, prior to the tank. In the cases where the primary source of the household water consumption was bottled water, the sample was collected from the water dispenser. Thus, one water sample was collected in 66 households, two samples were collected in 21 households and three samples were collected in 3 households. Therefore, a total of 117 samples were collected in 90 households.

Along with the collection of water samples, a questionnaire was performed to inquire into the following aspects: the household water source, the existence of an elevated water tank, the regular monitoring of the tank and whether it had a cover. Additionally, in households where water was obtained mainly from wells or boreholes, the

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residents were asked about the depth and the age of the wells, whether the borehole had a casing and filter, the date of the last analysis of the quality of the well water and the cost of said analysis. They were also asked to make a personal assessment of the quality of the water obtained from their wells and to justify their opinion. All respondents were also asked if they treated water used for drinking or cooking and if they bought bottled water. Another series of questions were asked to obtain information about the blackwater disposal system of the households (proximity of the leach field to the water extraction site, the frequency with which the septic chamber was emptied and the lifespan of the chamber).

The procedures for the collection and analysis of water samples were performed according to the *Standard Methods for the Examination of Water and Wastewater* (9). Water samples were collected in 250 ml sterile containers and transported to the laboratory under refrigeration according to methods 9060 and 9060B (9). The public network water samples containing chlorine were neutralized with sodium thiosulfate 0.1N sterile solution before the microbiological testing. The microbiological determinations were performed following the procedure described by Eaton *et al*. (9). Method 9221 was used for the total coliform count and method 9225 for the presence of *Escherichia coli*.

In addition to the analysis of fecal coliforms, total coliforms and *Escherichia coli*, an analysis of nitrate content (d) was performed for a subsample of 34 households. The determination of nitrate was performed according to the procedure described in Standard Methods 4500-NO_3^- Nitrogen (Nitrate) (9).

The sample was considered non-potable when the total coliforms were greater than 2 NMP/100ml, the *Escherichia coli* test was positive or the nitrate concentration was greater than 35mg/l (e).

The results of the bacteriological and nitrate analyses in water samples, together with the information obtained by means of the questionnaire, were inputted into the program *Statistical Package for the Social Sciences* (SPSS) version 15.0. This database was included in and annexed to a larger database (the framework from which the water sampling was obtained, based on the existence of precedents of waterborne disease), allowing for the incorporation of additional information into the initial base at both the individual and household levels. The additional information at the individual level consisted of: age, sex, education level, health coverage, employment status and self-reported suffering from waterborne diseases of each member of the household (the listed diseases were: diarrhea, hepatitis, dermatitis, intestinal infections, gastroenteritis, parasites and leptospirosis). Additional information at the household level included: information about the environmental context of the house, type of house, its building materials, number of rooms, the source and treatment of water, bathroom location and type of toilet flushing system and destination of the toilet drainage.

The final database was translated into a Stata/SE (version 10.1) format, which was the software used for the statistical analysis of the information. This analysis consisted mainly of calculating relative frequency tables, contingency or correlation tables, application of statistical tests of direct comparison of proportions (exact binomial test) and mean difference tests (Student's *t*-test). Additionally, regression models with dichotomous dependent variables were estimated to analyze the effect of the water origin and quality on the probability of suffering from waterborne diseases, controlling for possible confounding variables (such as age, sex and low educational level).

RESULTS

A total of 117 water samples were collected and analyzed, taken from 90 households (as mentioned in the previous section, more than one sample was collected in some households).

The distribution of the samples according to the water source was as follows: bottled water 18%, well water 35% and water from the public network 47%. The average age of the individuals from the sample was 32, and 52% were women. Regarding the self-reporting of waterborne diseases, it was observed that 45% of the individuals in the sample had suffered from a waterborne disease during the last year. Specifically, the prevalence of diarrhea among the individuals sampled was 29%; gastroenteritis 15%; dermatitis, intestinal

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infections and intestinal parasites 5%; and extraintestinal parasites 3%. It is worth mentioning that the universe consisted of households that had at least one member who had suffered from a waterborne disease in the last year, and therefore this prevalence cannot be extrapolated to the entire population. Thirty percent of individuals did not have any type of health insurance (public or private). Of the all the households sampled, 25% had heads of household (f) who had not completed primary school. There were also a high percentage of households for which the lack of asphalt (55%), frequent occurrence of flooding (48%) and dumps (58%) were problems in the neighborhood. The existence of substandard housing (g) represented a relatively low percentage of the sample (2%), demonstrating that the samples did not come from precarious settlement areas, which are *a priori* the most vulnerable areas in Greater Buenos Aires (the so-called shantytowns or informal settlements). However, 60% of the total sample indicated that the toilet drainage did not discharge into the public network, that is, the households were not connected to the sewage system.

On the basis of the potability criteria detailed in the Methods section, the water sample analyses showed the following results: 40% of the samples were deemed "non-potable" due to an excess content of fecal coliforms, total coliforms, and/or *Escherichia coli*.

Taking into account the excess of nitrates (which was analyzed for only one-third of the sample), 35% exceeded acceptable levels. In the joint analysis of coliforms, *Escherichia coli* and nitrates, the percentage of "non-potable" water samples reached 44%.

The graphical representation of the results of non-potability according to water source can be seen in Figure 1 (for fecal coliforms, total coliforms, and Escherichia coli) and Figure 2 (for nitrates).

Figure 1 shows that, according to the bacteriological results, 9% of the water samples collected from the water supply network were "non-potable," while this percentage was 45% for bottled water samples and 80% for well water samples. Although there are evident differences depending on the water origin, a statistical test of comparison of proportions was applied and showed that the differences in all cases were statistically significant at 1%.

Figure 2 shows that none of the bottled water samples (5 in total) exceeded the acceptable levels of nitrates, while 12% of the public water network samples and 83% of well water samples had an excess of nitrates.

All of the public network water samples that were non-potable according to the bacteriological study were collected after having been stored in tanks or after having passed through some type of filter (they were not samples directly collected from the water supply network before having been stored in tanks or having passed through an individual filter system). However, 8% of the water samples collected directly from the public water network (2 cases out of 26) were non-potable due to excess of nitrates.

As regards the well water samples, there were no significant differences in the percentages of non-potable samples according to whether they were samples collected directly from the well or from water stored in a tank. In the first case (non-potable samples from the total of well water samples directly collected from the well) the percentage was 20%, and in the second case (non-potable samples from the total of well water samples stored in tanks), 19%.

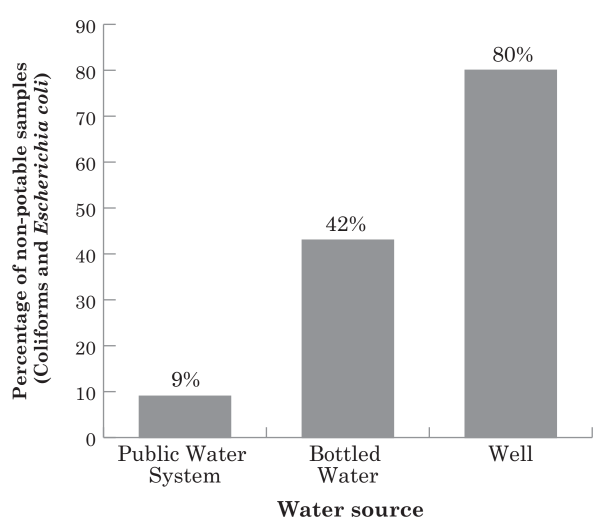

Figure 1. Percentages of non-potable water samples due to excess content of fecal coliforms and *Escherichia coli*, by source. Matanza-Riachuelo river basin, 2011.

Source: Own elaboration using primary data.

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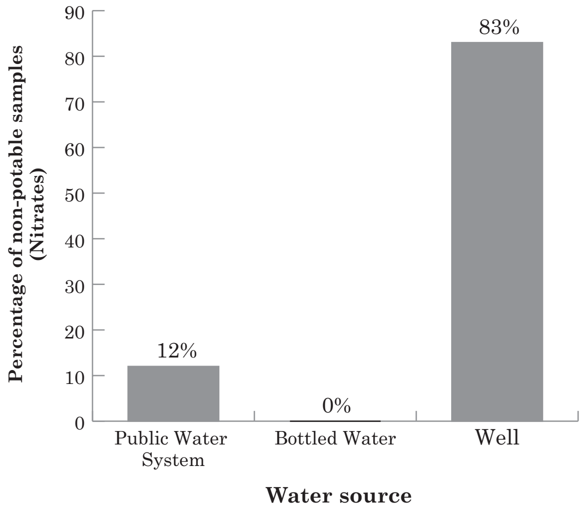

Figure 2. Percentages of non-potable water samples due to excess content of nitrates, by source. Matanza-Riachuelo river basin, 2011.

Source: Own elaboration using raw data.

After analyzing the survey responses regarding the depth of individual water wells, and adopting a 40-meter depth as the singular contrast value (as in the region there is a high probability of reaching the roof of the Puelche aquifer and, therefore, groundwater of better quality) the following observations can be made:

- Of the 27 well water samples collected, 6 were negative for the bacteriological parameters (22%) and 21 were positive (78%).
- Of the 6 negative samples, 4 were collected from wells deeper than 40 meters (67%) and 2 from wells with lesser depths (33%).
- Of the 21 positive water samples, 10 were from wells deeper than 40 meters (48%) and 11 from wells with depths of less than 40 meters (52%).

As for the presence of nitrates in the wells whose depth was known, of a total of 5 wells with depths less than 40 meters, 4 exceeded the allowed limit for nitrates (80%) and 1 did not. Of the 3 wells with depths deeper than 40 meters, all exceeded the allowed limit for nitrates (100%).

Two more wells with unknown depths exceeded the nitrate limit. In summary, of the 11 samples collected from the individual wells where nitrate was analyzed, 10 were "non-potable" and 1 did not exceed the nitrate levels, regardless of well depth.

The results presented in the two preceding paragraphs reveal that water from individual wells is mostly non-potable, regardless of well depth. This highlights two core issues. On the one hand, it shows the degree of anthropogenic deterioration (characterized by the presence of nitrates) of the Puelche semi-confined aquifer, historically known for its good quality and low vulnerability. On the other hand, it raises questions about the efficiency of the isolation between contaminated and uncontaminated aquifers reached in individual boreholes (both household and industrial).

The difference between negative and positive samples (according to bacteriological analyses) in the proportion of households that reported wells with casing and filter was significant. In the first case (samples which did not exceed the acceptable levels), 67% of the wells had casing and filter, whereas for the "non-potable" samples the percentage was 48%. Although this difference was significant, the result must be treated with caution due to the high non-response rate for this question. Further studies are needed to draw conclusions.

In order to assess the extent to which the water source represents a health risk (within the population group included in the sample), a series of logistic regression models were estimated at the individual level, with the dependent variable equal to 1 in cases of self-reporting of disease.

Table 1 presents the odds ratio of the parameters of interest with their respective statistical significance (*p*-value) for the logistic models of each of the diseases. The dependent variables include having suffered from "at least one of the waterborne diseases" and the rest of the diseases specifically addressed in the study for which there were cases reported. These diseases are: diarrhea, gastroenteritis, intestinal infections, intestinal parasites and dermatitis. The independent variable under study is the "water source," a dichotomous variable with a value of 1 if the main source of the water for home consumption was an individual well and a value of 0 in the other cases (public water network or bottled water). The control variables include age, sex and a dichotomus variable which took the value of 1 for people aged 15 years or older who had not completed primary school.

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Table 1. Logistic estimates of the probability of suffering from waterborne diseases with "water origin" as an explanatory variable (robust estimate of the variance). Matanza-Riachuelo river basin, 2011.

	Explanatory variables							
	Age		Sex		Water source		Incomplete primary education	
	Odds ratio	*p*-value	Odds ratio	*p*-value	Odds ratio	*p*-value	Odds ratio	*p*-value
Some waterborne diseases	1,00	0,90	1,03	0,75	1,55	0,06	1,76	0,03
Diarrhea	1,01	0,04	0,93	0,35	1,87	0,01	1,35	0,29
Gastroenteritis	0,99	0,23	0,96	0,51	1,16	0,63	0,86	0,67
Intestinal infections	1,01	0,14	0,97	0,78	0,25	0,06	1,66	0,35
Intestinal parasites	0,97	0,09	1,14	0,19	1,90	0,22	1,08	0,89
Dermatitis	1,00	0,66	0,94	0,70	2,60	0,04	0,86	0,80

Source: Own elaboration using primary data.

[a]The category of reference was male.
[b]The category of reference was water from the public network or other source, except from a well.

Results show that the water source (well) has a positive and statistically significant effect on the probability of suffering from a waterborne disease and, specifically, on the probability of suffering from diarrhea, intestinal infections and dermatitis. The odds ratios for gastroenteritis and intestinal parasites were also greater than one, but were not statistically significant.

The magnitude of the estimated odds ratios indicates that:

- Individuals living in households where individual wells are the main source of water used for consumption have a 55% higher probability of suffering from a waterborne disease than those living in households where the main water source is the public water network or bottled water.
- The probability increases 87% for diarrhea and 160% for dermatitis.

It is worth mentioning that the variable "water source" is statistically significant in the mentioned cases, even after controlling for a proxy variable for socioeconomic status based on educational level as well as for demographic variables (age and sex).

DISCUSSION

The lack of basic sanitation services (specifically connections to the public water and sewage systems) has been widely mentioned as a risk factor to health. Several studies show that the lack of coverage of these services is critical in the contraction of waterborne diseases in different regions of the world, and some studies quantify the effects of this deficit in terms of health or in terms of the economic impact (5-7,10-17).

The deficits in sanitation services in the counties of Greater Buenos Aires are surprising not only because of their magnitude, but also because the counties are located mere kilometers from one of the areas with the highest coverage of sanitation services (and other services) in Argentina: the Autonomous City of Buenos Aires. Nevertheless, there is a lack of formal studies that analyze the relations among the origin of water for consumption, water quality and the presence of waterborne diseases in this area of Argentina.

Among the causes of the lack of coverage of such services, it is important to mention the characteristics of the urban growth of Greater Buenos Aires. In this sense, the work of Cravino *et al.* (4) is quite revealing: in Greater

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Buenos Aires, the population living in informal settlements has been growing much faster than the total population. Between 1981 and 2006, the population in shantytowns and settlements grew, in relative terms, 220% compared to the 35% growth in the population for the entire area. For logistical and safety reasons in the fieldwork, the selected sample did not include informal settlements; thus, the results obtained in this study can be considered conservative.

A recent study of the 17 counties of the first "ring" of Greater Buenos Aires (the counties closest to the Autonomous City of Buenos Aires) shows that over 30% of the population considers health, lack of pavement and flooding as priority issues in their neighborhood, while more than 50% consider dumps and unemployment to be critical problems (8). The study, based on a sample of 809 households where 3,038 individuals lived, also analyzed the impact of the lack of sanitation services on the probability of suffering from diarrhea, as well as the interaction between the lack of services and the low educational level of the head of the household and other variables measuring social and environmental vulnerability (for example, nearby dumps). The results were clear: the lack of sanitation services (public water and sewage systems) significantly increases the probability of suffering from diarrhea, and this effect is enhanced in especially vulnerable groups (there is an elevated positive interaction effect in the population with low educational levels and living near dumps).

The purpose of this study was to explore the mechanisms that might be affecting these relations and, in particular, to understand to what extent the water source may be a risk factor to health.

The main finding of this study is the high proportion of water samples which were not safe for drinking due to excess content of coliforms, *Escherichia coli* or nitrates (44% of the total sample), as well as the differences in the distribution according to the water source: 9% of the water samples from the public water system were non-potable, whereas this percentage was 45% for bottled water samples and 80% for well water samples.

It is worth emphasizing the very high percentages of non-potable water samples from individual water wells and even from bottled water. This result allows for a greater understanding of the mechanisms involved in the relation between the lack of sanitation services and the greatest risks to health. The poor quality of drinking water of the households without access to the public water system is a key factor in this relation. Furthermore, lack of access to the public water system cannot always be replaced by bottled water, since almost half of the analyzed cases showed that this water is not safe for drinking.

The high proportion of non-potable bottled water samples was a particularly surprising result. This highlights the need to strengthen quality controls in such cases and the importance of undertaking further studies of the origin of the bottled water sold in Greater Buenos Aires. It should be remarked that all non-potable bottled water samples were from unidentified brands or from little-known commercial brands that did not report the water source.

The characteristics and changes undergone in the drinking water sources of Greater Buenos Aires make it easier to understand the high proportion of households using non-potable water sources for consumption at present. The historical source of potable water in Greater Buenos Aires has been the semi-confined Puelche aquifer, a source located, on average, more than 40 meters deep with a variable thickness of 20 to 90 meters in the study area, characterized by a very high quality of water naturally. However, the quality has deteriorated as a result of the ongoing direct and indirect anthropogenic interventions which have made it so that the Puelche is no longer a safe source of drinking water (18,19). Although in the 1990s a process was begun to replace the water for human consumption from the Puelche aquifer with centrally treated water from the Río de La Plata, this process meant a solution only for the population with access to the public water system. The proportion of the population that still obtains water from individual or collective boreholes connected to the (contaminated) aquifer remains very high. Studies by Auge *et al.* provide a detailed description of the aquifers in the area and the aspects related with their vulnerability and deterioration (18-21).

Finally, the results of this study show that the waterborne diseases most correlated with the water source are diarrhea, intestinal infections and

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dermatitis. In such cases, the increased probability of suffering from the disease associated with the use of wells as the main water source is 87% in the case of diarrhea and 160% in the case of dermatitis.

One of the limitations in this analysis of the risk of suffering from waterborne diseases is that the cases used are not diagnosed but self-reported. However, since the aim of the study is not to obtain total or prevalence estimates but to analyze differentials between subgroups (in this case, between those with access to the public water system and those without access), underreporting would only affect the results if the underreporting were greater in one of the comparison groups. It could be expected that the group with greater underreporting will be the most vulnerable group (due to lack of information and access to health services and, therefore, lack of a proper diagnosis), but our results suggest the opposite: people without access to water from the public network (usually the most vulnerable population) are those with greater risks of suffering from diseases, suggesting that our results (if affected by this problem) are conservative.

In conclusion, based on the uncertainty regarding the efficiency in the drilling of individual water wells and the quality status of the Puelche aquifer in the Greater Buenos Aires area, water used for human consumption in this territory should come from centralized sources in order to ensure the quality control of water from the public network (coming in whole or in part from the Río de la Plata and nearby aquifers) which has been treated or suitably diluted as needed.

ENDNOTES

a. Greater Buenos Aires is made up of the Autonomous City of Buenos Aires (the capital city of Argentina) and the 24 counties (municipalities) of the Province of Buenos Aires that surround the capital city.

b. Households with a piped water supply inside the house or on the property that is connected to the public water system are included.

c. The Matanza-Riachuelo river basin includes part of the City of Buenos Aires and the counties of Almirante Brown, Avellaneda, Cañuelas, Esteban Echeverría, Ezeiza, General Las Heras, La Matanza, Lanús, Lomas de Zamora, Marcos Paz, Merlo and San Vicente.

d. Due to budget constraints, the criterion used in the laboratory analysis was to analyze the nitrates in 3 of the approximately 10 samples collected in each field research trip, all of which underwent the bacteriological analysis. The selection of the 3 samples was conducted randomly, although it was ensured that at least one nitrate analysis was done per census tract.

e. Although determining the potability of water follows a broader protocol than that of the indicated parameters, there is previous evidence that indicates these parameters (bacteriological and nitrate) to be among the most relevant for analyzing the potability in the area under study.

f. In Argentine sources, the head of the household is selected by "acknowledgment": that is, the head of the household is the person who is acknowledged as such by the other members of that household.

g. Precarious housing was considered broadly to include: tenement rooms, hotel/hostel rooms, structures not built for habitation, and shacks or hovels.

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ACKNOWLEDGMENTS

The present study was made possible thanks to the support from the National Agency for Promotion of Science and Technology of the Ministry of Science, Technology and Productive Innovation of Argentina, through project funds PICT 2008-1153 (Resolution 343-09). We thank the staff and members of the Unidad de Investigación Desarrollo y Docencia-Gestión Ambiental who contributed with their knowledge and best efforts in the survey design and the implementation of the fieldwork.

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CITATION

Monteverde M, Cipponeri M, Angelaccio C, Gianuzzi L. The origin and quality of water for human consumption: the health of the population residing in the Matanza-Riachuelo river basin area in Greater Buenos Aires. Salud Colectiva. 2013;9(1):53-63.

Received: 5 September 2012 | Revised: 25 November 2012 | Accepted: 5 February 2013

The translation of this article is part of an interdepartmental collaboration between the Undergraduate Program in Sworn Translation Studies (English < > Spanish) and the Institute of Collective Health at the Universidad Nacional de Lanús. This article was translated by Darío Damián Di Franco and Lucas Orellana, reviewed by Pamela Vietri and modified for publication by Vanessa Di Cecco.