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Water quality issues and infant diarrhoea in a South American province

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In the province of Salta, in the Northwest region of Argentina, almost two-thirds of the population live in absolute poverty, and diseases associated with poverty are rampant. Almost 12% of the total population of the province are children below five years of age; almost half of these infants are living in situations where the basic necessities are not available. Primitive sanitary conditions, including widespread contamination of available water supplies with pathogens, contribute to a major public health problem. Infant mortality was 17% higher for Salta than for Argentina as a whole in 2001. A major cause of death for these children is infectious disease, especially respiratory and intestinal diseases. In Salta, more than half of the total population of infants is affected by diarrhoea annually. The infectious pathogens are diverse: bacteria (predominantly in spring and summer), viruses (especially in the winter) and parasites (endemic in some situations). This paper evaluates current methods used to test for the presence of pathogens in drinking water; discusses why these methods are less than adequate; documents an episode of contamination in a local water supply source; and suggests appropriate methods that can be used to better address this major public health issue effectively.

Keywords: infectious disease; public health policies; poverty; Latin America; infant mortality

Introduction

In Latin America, economic globalisation has meant the increased movement of people and goods and changes in environmental and occupational health hazards, often occurring in the context of political and economic instability. It has also meant that health risks are being transferred. Of the estimated 183 million people living in poverty in Latin America, more than half are children and teenagers, 72% of them live in urban areas, and mortality and morbidity impact especially the infant population, from zero to five years old (Puga 2001). Acute respiratory infections (mainly pneumonia), diarrheoa, measles, malaria (and frequently a combination of them) are the most common causes of morbidity and mortality among children under the age of five in the developing world, with diarrhoea and respiratory infections being the two most common causes. Diarrhoea can be defined as loose, watery and frequent stools. It is considered chronic or persistent when loose or frequent stools last for more than two weeks. The World Health Organisation (WHO) estimates that about 1.5 million deaths per year from diarrhoeal diseases, mainly in children, are attributable to environmental factors such as contaminated drinking water,

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poor sanitation and poor hygiene (Prüss-Üstün and Corvalán 2006). This report observes that a large portion of the total burden of diarrhoeal disease is caused by fecal-oral pathogens from both human and animal sources. It has been estimated that diarrhoeal diseases accounted for 5.3% of deaths and 3.5% of Disability-Associated Life Years (DALY's) in European children aged 0–14 (Valent et al. 2004).

Malnutrition frequently accompanies these diseases, and is a primary factor contributing to the complications of both diarrhoea and pneumonia, although the causal links and mechanisms remain unclear. Other factors than the nutritional status of infants and children influence the incidence of diarrhoea, including socioeconomic status, disruption of traditional lifestyles, accessibility to clean water and sanitation facilities, age and their breast-feeding status. Infants and children throughout the developing world suffer many episodes of diarrhoea each year. Diarrhoea of any duration may have adverse effects on a child's health, especially due to the potential for producing cumulative negative effects on nutritional status. However, major morbidity results from complications of acute diarrhoea and dehydration, as well as the development of persistent diarrhoea. These complications are responsible, in turn, for the great majority of diarrhoeal mortality (Schorling 1996).

With the use of oral glucose-electrolyte rehydration solution, the vast majority of deaths from acute, non-invasive diarrhoeas could be prevented. However, a group of more chronically debilitating, persistent diarrhoeas are emerging as a major health problem. There are many possible mechanisms of persistent diarrhoea, including anatomic considerations, allergic phenomena, manifestations of systemic disease and infectious agents. However, most of these have not been seriously examined in the context of children in the developing world. There are many explanations for the complex syndrome of persistent diarrhoea in children. It seems that many host factors (malnutrition, immune status, etc.) and sociocultural considerations (age of weaning, concepts of child care and cultural definitions of health and disease states) are inseparable from the microbiological and gastrointestinal physiological causes.

In Argentina, emerging infectious diseases have increasingly been detected, starting with epidemic outbreaks of Argentine hemorrhagic fever (AHF) in the 1950s, human immunodeficiency virus infection (HIV)/AIDS and leishmaniasis in the 1980s, and cholera, antimicrobial resistance, hantavirus and dengue in the 1990s (Segura 2001). These illnesses are related to deterioration of the public and individual environment. Other illnesses, like trichinosis, are more dependent on the quality of alimentation. Tuberculosis and Chagas are also present with a high impact in the north of the country (MSA and PAHO-WHO 2003).

Diarrhoea in Argentina and in Salta

The total number of children in Argentina below five years old is around 3.5 million, about 9.4% of the population. About 130,000 of these infants are in Salta province, representing almost 12% of the population. In Salta, 62% of the total population lives in absolute poverty, and about 42% of the infants (under five years old) are living in situations where the basic necessities are not available (SAP-UNICEF 2003). These indexes are reflected in the sanitary situation.

For Argentina, the infant mortality was 16.3 per thousand births, and the neonatal mortality was 10.6 per thousand in 2001, while comparable data were 19.1 and 11.4 for Salta, respectively. After external causes of death and congenital malformations, deformations and chromosomal anomalies, the main causes of death are infections, respiratory and intestinal in many cases (Durán 2003). In Salta, diarrhoeas mainly affect the infant population; between 1998 and 2002, the number of victims from acute diarrhoeas increased from 63,300 to 73,300 cases per year in the province, thus affecting about half (49–52%) of the total population of infants annually. The diarrhoea data were reported by the Epidemiological National Survey System (SINAVE), compiled from Statistical Reports of Ambulatory Medical Assistance that include: date of assistance, complete name, gender, age (in years for older than one, and in months and days for younger), address and diagnosis (diarrhoea in this case). The infectious pathogens are diverse: bacteria (predominantly in spring and summer), viruses (especially in the winter) and parasites (endemic in some situations).

The last deep economic and social crisis occurred in 2001 after many years of economic recession. It impacted all aspects of life, but especially socially critical aspects such as access to work, food, education and health. These impacts were concentrated in the poorest groups of the population. The public health budget was mainly used for emergencies, while prevention was neglected. The number of diarrhoea cases reflected this situation, and also the recovery of the national economy that started slowly in 2003 and demonstrated strong growth from 2004 onwards (see Figures 1 and 2).

Salta's economic situation reflected that of the national economy; however, Salta had a greater rate of economic growth, since it became a favourite destination for international tourists. The diarrhoea case numbers decreased, as did the incidence rate with respect to that for the whole country; however, it was still 3.5 times higher than in 2004 (see Figure 3).

Pathogens causing diarrhoea

The principal pathogens responsible for causing persistent diarrhoea have long been recognised to be the parasites *Giardia lamblia* and *Entamoeba histolytica*. However, numerous other enteric pathogens, including bacteria (*Escherichia coli*, *Shigella*, *Salmonella*, *Campylobacter*, *Aeromonas*, *Clostridium dificile*), mycobacteria (*Mycobacterium*

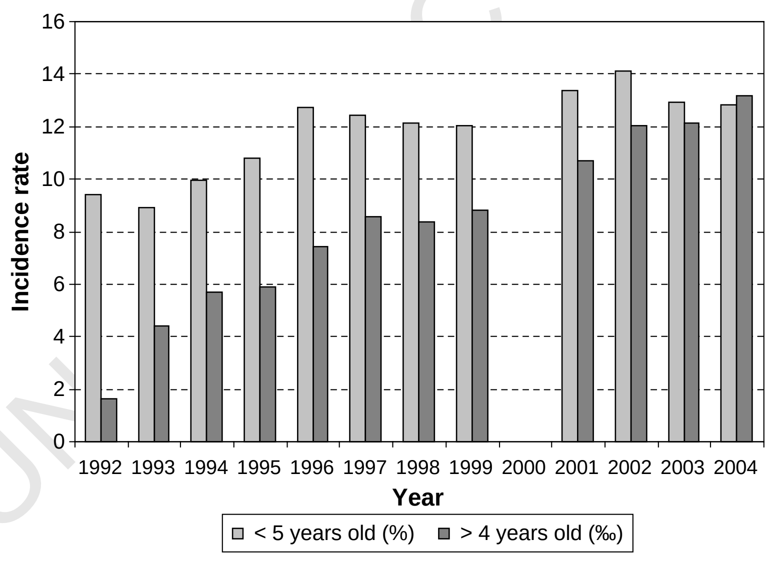

Figure 1. Incidence rate of diarrhoea in Argentina. Source: Epidemiological National Survey System (SINAVE), National Health Ministry (Information for 2000 was not available). Data available at http://www.direpi.vigia.org.ar/publica_anual.htm.

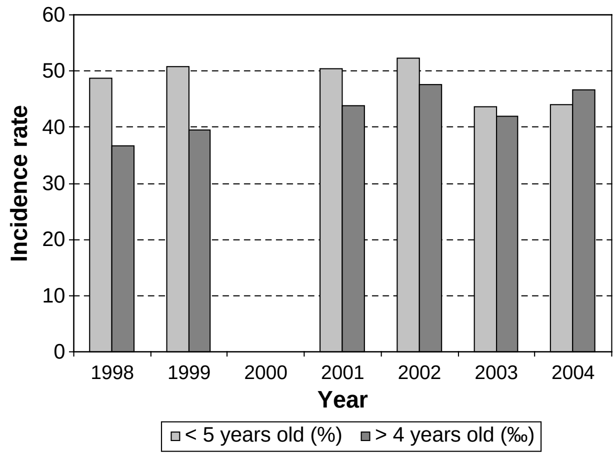

Figure 2. Incidence rate of diarrhoea in Salta. Source: Epidemiological National Survey System (SINAVE), National Health Ministry (Information for 2000 was not available). Data available at http://www.direpi.vigia.org.ar/publica_anual.htm.

tuberculosis and *Mycobacterium avium-intracellulare*), viruses (rotavirus, adenovirus, enterovirus, Norwalk-like viruses, pestivirus, astroviruses, etc.), fungi (the role is not clear but *Candida* is frequently associated with persistent diarrhoea) and other parasites (*Microsporidia*, *Strongyloides stercoralis*, etc.) can also contribute to more persistent, as well as to acute, diarrhoeal illnesses (Wanke et al. 1996). The pathogenic parasites and bacteria on this list have been well studied; numerous drug treatments have been developed that are accessible and affordable for most of the population. Viruses are difficult to detect and because of the lack of effective treatments the main strategy to decrease viral impact must be prevention.

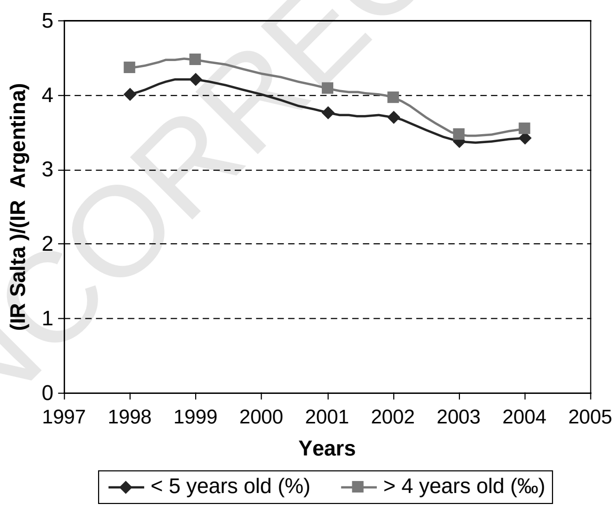

Figure 3. Incidence rate (IR) of diarrhoea in Salta referred to the national amount. Source of data: Epidemiological National Survey System (SINAVE), National Health Ministry. (Information for 2000 was not available). Data available at: http://www.direpi.vigia.org.ar/publica_anual.htm.

The main route of exposure in infectious diarrhoea is oral-fecal. Contaminated water and foods are the principal carriers of human-specific pathogens. Poor hygiene is also considered a major cause. More than 15 different groups of viruses, including more than 140 distinct types, have been found in the human intestine and may be discharged to the aquatic environment in wastewater (Leclerck et al. 2004). The viruses identified with higher morbidity rates for grastrointestinal diseases are rotavirus, astrovirus, norovirus (NoV), adenovirus serotypes 40 and 41 and enterovirus.

Rotavirus is the main cause of diarrhoea hospitalisations among children worldwide. Rotavirus reportedly caused approximately 22% of childhood diarrhoea hospitalisations between 1986 and 1999, and the proportion increased to 39% from 2000 to 2004 (Parashar et al. 2006). Rotavirus annually causes 111 million episodes of diarrhoea requiring home care only, 25 million clinic visits, two million hospitalisations, and an average of 440,000 deaths in children under the age of five years, 82% of whom live in developing countries (Parashar et al. 2003). In Argentina, studies showed the high impact of infection (Giordano et al. 2001), identified the prevalent serotypes (Bok et al. 2001, Castello et al. 2006, Stupka et al. 2007), and showed the economic benefits (direct medical cost savings) of effective vaccination (Gómez et al. 1998).

Human astroviruses (HAstVs) are associated with gastrointestinal illness, especially in children; they also produce diarrhoea in adults and immunocompromised patients. These viruses may be responsible for outbreaks in schools, daycare centres, and other closed populations. Astrovirus was found in 40/1070 (3.7%) of fecal specimens collected in Mendoza over a three-year study period. Of the 1070 children studied, 62% required hospitalisation and HAstVs was found in 3.9% of these cases. Among outpatients, the virus was detected in 3.5% of 402 children (Espul et al. 2004). Another epidemiological and clinical study, carried out in Cordoba, reported that astroviruses contributed 12.4% of the overall morbidity from diarrhoea (Giordano et al. 2004).

NoV, a calicivirus, is a major causative agent of viral gastroenteritis, affecting all age groups worldwide (Radford et al. 2004). NoVs are genetically and antigenically diverse and cannot be cultured, which made diagnosis and identification difficult historically. Newer molecular methods for identification have solved this problem. In Argentina, the first work on Norwalk-like virus and Sapporo-like virus (also caliciviruses) variability was studied in children with diarrhoea in Mendoza (Martinez et al. 2002).

Adenoviruses cause respiratory diseases (bronchitis, pneumonia, broncheolitis), pharyngoconjunctival fever, gastroenteritis, epidemic keratoconjunctivitis, encephalomeningitis, and herpes. Serotypes 40 and 41 are major causes of diarrhoea in children and are AQ2 of sufficient concern to public health to have been placed by the US EPA on its Contaminant Candidate List for drinking water (Ko et al. 2005). In Cordoba, Argentina, a study on 133 cases of hospitalised children with acute diarrhoea identified several viruses, including rotavirus 84%, astrovirus 10.7%, adenovirus 40/413.6% and dual rotavirus-astrovirus infection 1.7% (Giordano et al. 2001).

The human enterovirus family, which includes poliovirus, echoviruses and Coxsackie A and B viruses, produces various diseases such as meningitis, encephalitis, poliomyelitis, cold, stomatitis-herpangina-hand-foot-mouth syndrome, pharyngitis, myocarditis, neonatal sepsis, diabetes mellitus, and gastroenteritis (Liste et al. 2000, Nowak-Wegrzyn et al. 2001, Elfaitoure et al. 2005). In Argentina, a viral meningitis outbreak in Tucuman was detected in 2003 (Freire et al. 2003), and enterovirus was related to central nervous system infections (Mistchenko et al. 2006).

Microbiological quality of water

The microbial quality of water resources and the management of microbial-laden wastes generated by animal and agricultural industries are critical local, regional and national problems. Animal wastes can contain high concentrations of microorganisms that are pathogenic to humans. In addition, urban storm events may convey significant numbers of pathogens to areas where they can persist, providing risk during subsequent exposure. The presence of human pathogens in source water has been a concern of municipalities because disease-causing agents may have negative health implications for those individuals that come in contact with the water. In addition, the level of source water contamination may be used to determine the extent of treatment processes needed to ensure public safety.

Current regulations are based on the use of culture-based methods for the detection of indicator organisms. Coliforms have been used as indicator organisms for the microbiological quality of water and serve as the basis for regulations and policy guidance. However, many studies have demonstrated that coliforms are not representative of certain kinds of contamination (Hardina and Fujioka 1991, Ferguson et al. 1996, Schroeder et al. 2002). A large epidemiological study that examined the health risks along Mission Bay Park in San Diego did not find any correlation between indicator bacteria and illness contracted by beachgoers (results presented at the National Beaches Conference, San Diego, 2004). Thus, decisions based on detection of indicator organisms often result in significant costs and may have no benefit to public health. Since these methods are based on microorganism viability, results may give an underestimation of the real contamination. In addition, many pathogens cannot be cultured using conventional means.

Coliform indicators may have various sources (animals, birds, reptiles, soil); thus, demonstration of the presence of coliforms in a water sample may not document a direct relationship with human fecal material. Conversely, enterovirus and adenovirus are human-specific and indicate that water has come into direct contact with human pollution (Noble et al. 2003). For indicator bacteria to be useful as a public health tool, increased counts should correlate with the presence of human-specific viruses. Positive results for fecal coliforms (FC) do not tell about the origin, either human or animal, of the contamination, an issue that must be considered at the time of assessing the risk for public health. A wide range of alternative microbial and chemical indicators have been investigated for potential differentiation of fecal sources (Scott et al. 2002, Gilpin et al. 2003, Kildare et al. 2007). Many new watershed protection initiatives are focusing on emerging technologies for the identification of sources of fecal contamination. This approach, called Microbial Source Tracking (MST), relies on genetic profiles of microorganisms using either cultured or uncultured target cells. The US Geological Survey Water Quality Office maintains a database and bibliography on emerging techniques in MST (http://water.usgs.gov/owq/microbial.html).

MST based on the detection of *Bacteroidales* (Bernhard and Field 2000) appears to be a promising tool for detecting microbial contamination in water. This method has been used in several studies (Colford et al. 2007), including the Mission Bay Bacterial Source Identification Study (Gruber et al. 2005) and the Calleguas Watershed study (Kildare et al. 2007), and revealed that high indicator counts can be attributed to non-human sources, such as birds near beaches. It is likely that routine coliform counting done in Salta (and elsewhere) is systematically overestimating the risk from *E. coli* and *Salmonella*, while totally ignoring more serious threats from various non-bacterial pathogens. Interestingly, no signal for human-derived 16S rRNA genes of *Bacteroidales* was found at storm drains. The *Bacteroidales* group consists of anaerobic, fecal bacteria, which are good indicators of fecal pollution in a body of water. In comparison to coliform counts, the molecular-based detection of *Bacteroidales* offers a precise method and specific target group (Dick et al. 2005), whereas various microbial groups contribute to coliform counts. Both human and non-human sources contribute *Bacteroidales* and coliform-forming bacteria to water sources, so MST is a powerful tool to classify the types of contamination. The rapidly growing database of *Bacteroides* sequences from humans and various animals will make it possible to design Polymerase Chain Reaction (PCR) primers and probes that not only differentiate, but also quantify, the contribution of *Bacteroides*-fecal contamination by specific sources. This method has a huge potential for tracking the source of microbial contamination; however, the research area is new, and a correlation between human-derived *Bacteroidales* sequences and the presence of human pathogens has not yet been established.

Human-specific viruses are the cause for numerous infectious illnesses, and can potentially be used as a tracer of human fecal contamination. Human adenoviruses and enteroviruses have been frequently found in urban rivers associated with human fecal contamination as well as in polluted coastal waters. European studies have suggested using adenovirus as an index of human viral pollution since this virus has often been detected in samples contaminated with human fecal material (Pina et al. 1998). Similarly, enteroviruses found in activated sludge, sewage outfalls, and fresh and marine waters are also associated with human fecal contamination (Noble et al. 2003).

Other methods besides culture-based detection of microorganisms are also available. The use of molecular techniques has increased tremendously in recent years with improvements in technology and knowledge. These methods offer the advantages of sensitivity, specificity, selectivity and rapid results. All these aspects are crucial when making decisions related to human health risk. Protocols for the PCR, non-quantitative or quantitative, are continuously being developed. There are a wide variety of publications and references related to the detection of pathogens (bacteria, viruses or parasites) by PCR in different kinds of samples. However, environmental samples (soil [illegible]ter) are complex

AQ2 matrixes that can contain many different substances that inhibit the DNA amplification reaction, thereby decreasing the detection limit of the method (Wilson 1997, Cullen and Hirsch 1998, Harry et al. 1999, Chandler et al. 2000, Burtscher and Wuertz 2003, Straub and Chandler 2003, Rajal et al. 2007a, 2007b). The number of viruses in water can be very low, so the concentration of water samples prior to PCR analysis becomes a necessity. Quantitative recovery of viruses can prove to be a difficult task due to low recoveries of virus because of losses during conventional filtration (Schroeder et al. 2002). Tangential ultrafiltration by hollow fiber seems to allow better recovery of viruses (Winona et al. 2001, Morales-Morales et al. 2003). Methodology to optimise the efficient recovery of human viruses from water was recently developed and validated (Rajal et al. 2007a).

Water quality issues and diarrhoea in Salta

The Arias and Arenales rivers join together west of Salta (capital city of Salta province) to form the Arenales River ~~(Does this make sense?)~~. The river runs through much of the Province of Salta; initially through a semi-rural area where the main uses are water supply for a drinking water plant (DWP), agricultural irrigation and fresh water for livestock maintenance. After that, the river crosses the city of Salta and continues to the south to discharge in the Cabra Corral reservoir, which provides water for different uses and for hydroelectric energy to locations downstream.

The city of Salta has grown a great deal in the last decade. This growth was not organised and population expanded to occupy places where the basic services (water, sanitation) were not available. Crossing the city, the river receives the impact of point and non-point source pollution: illegal discharges of domestic wastewater without treatment, storm water, illegal and improper solid waste disposal, and discharges of industrial effluents. The water is used for many purposes: domestic in the poorest areas (hygiene, cooking, watering plants and vegetables that are grown for self consumption, animals, etc.), recreational where children are the users, and industrial. The population exposed to such impacts is significant. Studies on chemical contamination showed the necessity of regular monitoring of the river (Musso 2000). Salta's Provincial Environmental Laboratory currently measures some physicochemical parameters, inorganic compounds and indicator bacteria (but not viruses because the technology was not available) at a few locations. Real-time PCR assays are currently being set up for that purpose.

Current water legislation establishes that microbiological quality of water is assessed by measurement of indicator bacteria: total coliforms (TC) and FC. We have analysed TC and FC (Most Probable Number method, MacConkey Broth (Eaton et al. 1998), in the Arenales River and an associated irrigation channel in a semi-rural area west of Salta during the dry season (June–August 2006). Average mean temperature in this region is 17.1°C and average mean rainfall is about 67 cm. There is a plant in this area that makes drinking water for the local municipalities. Four sampling sites were chosen at the river (R1–R4, Figure 4) and at the irrigation channel (C1–C4, Figure 4). Additionally, samples at the local school (S, Figure 4) were analysed from the water supply network (S–T) and from their own well (S–W), both sources of drinking water at different times of the day.

Our results (see Table 1) showed counts exceeding existing standards for TC and FC (see Table 2) in two-thirds of the samples analysed. There are many farms (mainly avian) on the margins of the river and the channel. In particular, there is a large one between R2 and R3 and six others right before C3. This site (C3) also receives the impact of a stabilisation pond and of a mini-dump. Lower TC and FC counts verify the remediation capability after R3 and C3. This high-risk situation for public health becomes worse due to some socioeconomical issues. The farmers need additional help during harvest and the usual solution is to hire cheap temporary workers, usually from Bolivia, who work seasonally. These 'golondrina' workers are usually illegal immigrants living within minimal hygiene and sanitation conditions. They often drink raw water from the irrigation channel during work.

The water fed into the DWP (Figure 4), according to our results for sample C4 (Table 1), exceeded the guidance values for TC and FC considering that only filtration and disinfection (option *a* in Table 2) are performed. Proof of the defective product was the contamination found in the drinking water sample (S–T) from the school (S in Figure 4), which is located 100 m from the DWP. The other source of drinking water there, groundwater, presented a TC value in excess of the Guidance value (S–W, Table 1). This is a frequent problem for that area since most of the wells (including private properties) are not deep enough (3–10 meters) to be isolated from the high environmental burden, taking into account the characteristics of the soils.

Diarrhoea episodes are very common in the area. Unfortunately, epidemiological information, specifically related to the river and irrigation channel area of influence, is not available. However, mandatory notification, including for diarrhoea, from this and other surrounding areas (from the total population of 12,149 inhabitants, 50% live in urban zone, 35% in semi-urban, and the remaining 15% in high mountains) is registered at the Campo Quijano Health Centre (county seat) (see Table 3). The incidence of gastrointestinal disease

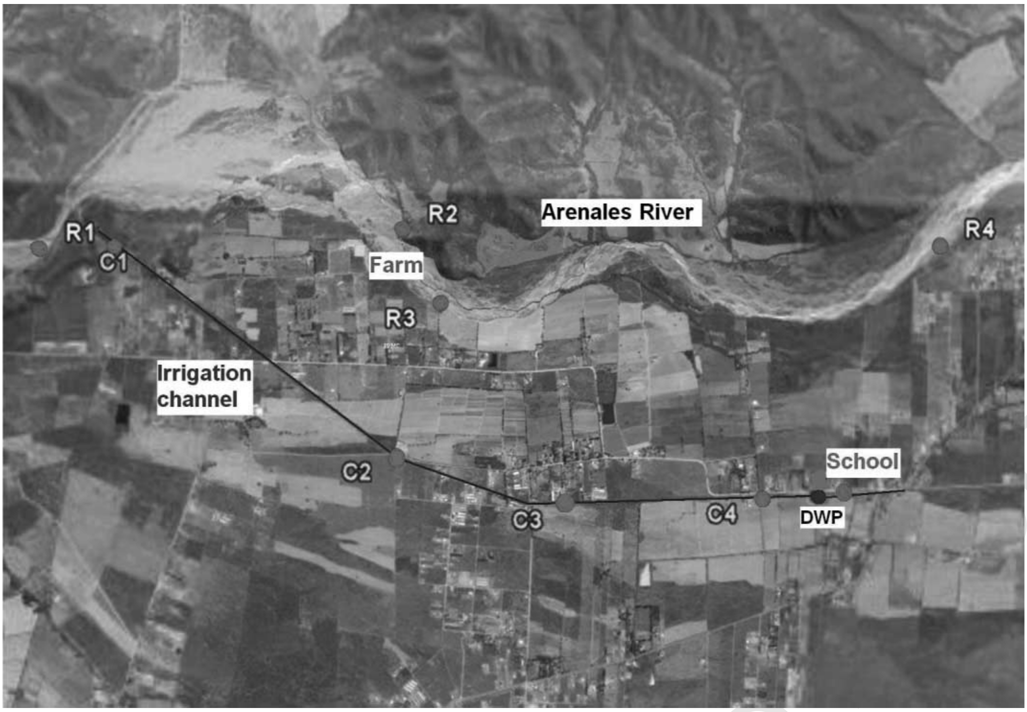

Figure 4. Sampling locations (Red spots) at a semi-rural area, west of Salta. Surface water samples were analysed from the Arenales River (R1–R4) and from the irrigation channel (C1–C4). Drinking tap water from the local school comes from the Drinking Water Plant (DWP, blue spot).

is very high among this population, where approximately one person out of seven had an episode that year severe enough to seek medical assistance. The global incidence rate of diarrhoea (149‰), presented in Table 3, is high; however, the infant (<5 y) incidence rate is 415‰, almost three times greater, showing the high vulnerability of that age group. Infant diarrhoea accounted for approximately 35% of reported cases. The etiological agent was generally not determined, nor were further actions taken to modify the public health situation.

Geographical Information Systems (GIS) analysis of data from the year 2005 (data not shown) showed that the areas close to the Arenales River presented the highest Standard Morbidity Rate for parasitosis, supporting our hypothesis that contamination of available water supplies with pathogens significantly contributes to a major public health problem, childhood and infant diarrhoea, in Salta.

Discussion

According to the WHO, an estimated 24% of the global disease burden and 23% of all deaths can be attributed to environmental factors. These numbers differ strongly from non-developed countries (350–500 deaths/100,000 population) to industrialised countries (100–150 deaths/100,000 population). Diseases with the largest absolute burden attributable to modifiable environmental factors included, in order of decreasing morbidity rate: diarrhoea, lower respiratory infections, 'other' unintentional injuries and malaria. In

Table 1. Total (TC) and fecal (FC) coliforms determined in water samples from the river (R1–R4), from the irrigation channel (C1–C4), and from school drinking water (S–T: tap water from water supply network; S–W: groundwater from their own well).

Sample	Distance (Km)	pH	TC (MPN/100 mL)	FC (MPN/100 mL)
R1	0	7.0	36	36
R2	3.2	7.1	430	36
R3	3.9	7.9	21,000	2300
R4	8.9	8.0	1500	230
C1	0.33	7.0	30	30
C2	3.03	7.3	1500	30
C3	4.53	7.4	23,000	91
C4	6.03	7.4	2300	430
S–T	6.5		150	36
S–W	6.5		390	Negative

particular, an estimated 94% of the diarrhoeal burden of disease is attributable to environmental causes and associated with risk factors such as unsafe drinking water and poor sanitation and hygiene (Prüss-Üstün and Corvalán 2006). However, the etiological agent of diarrhoea is seldom identified.

The human and economic costs for waterborne diseases are high in developed countries, and even higher in developing countries. Investigation of waterborne diseases

Table 2. Guidance values for total (TC) and fecal (FC) coliforms in water for different uses according to Argentinean Alimentary Code (CAA 1979), World Health Organisation (WHO 2006), European Community (EC 1975), and Guidelines for Canadian Recreational Water Quality (FPWGRWQ 1992).

Use		TC/100 mL	FC/100 mL
Drinking		<3 (CAA 1979)*, 0 (WHO 2006)	0 (CAA 1979)*, 0 (WHO 2006)
Recreation		10000[§], 500[#] (EC 1975)*	2000 (FPWGRWQ 1992**, EC 1975[§])100[#] (EC 1975)
Irrigation		1000 (FPWGRWQ 1992)**	100 (FPWGRWQ1992)**
Surface water, inlet of drinking water plant, according to treatment applied (EC 1975)[#]	(a)	50	20
	(b)	5000	2000
	(c)	50,000	20,000

Note: Methods of treatment for transforming surface water into drinking water: (a) Simple physical treatment and disinfection, e.g. rapid filtration and disinfection. (b) Normal physical treatment, chemical treatment and disinfection, e.g. pre-chlorination, coagulation, flocculation, decantation, filtration, disinfection (final chlorination). (c) Intensive physical and chemical treatment, extended treatment and disinfection, e.g. chlorination to break-point, coagulation, flocculation, decantation, filtration, adsorption (activated carbon), disinfection (ozone, final chlorination).
*Minimal frequency of 15 days; **Geometric mean of a minimum of five analysis in 30 days; [§]Mandatory; [#]Guideline.

Table 3. Number of cases registered at the Herrera Hospital, Campo Quijano, in 2005, and incidence rate of diarrhoea and parasitosis by age.

Age (years)	Cases	Population	Incidence rate (‰)
<1	151	302*	500.3
1	223	302*	738.9
2–4	253	905*	279.4
5–9	126	1604	78.6
10–14	56	1360	41.2
15–24	90	2244	40.1
25–34	88	1587	55.5
35–44	90	1181	76.2
45–64	118	1812	65.1
>65	57	852	66.9
Not specified	559	12149	46.0
Total diarrhoea	1811	12149	149.1
Total parasitosis	530	12149	43.6

*For infants up to four years old, the population data available was not discriminated by age (1509 total). In order to calculate the incidence rate by age it was assumed that the population distribution per year old was uniform (1509/5). For the age classes involved the total population was calculated as: 1509/5 for <1, 1509/5 for one year old, and (1509 × 3/5) for 2–4 years old.

helps to reduce those costs by limiting the transmission (once an outbreak has occurred), identifying and controlling the underlying problems causing disease, and identifying trends.

Many modern tools (technology and techniques) are available, and are being developed, to conduct true time-space queries in public health: new diagnosis systems, novel methodology for pathogen detection, Global Positioning Systems (GPS), GIS, Internet, accessible software, remote sensing, and Quantitative Microbial Risk Assessment (QMRA).

Poor quality water is one of the main causes of diarrhoea in the world. However, the true correlation between diarrhoea and polluted water is barely established. GIS offers the possibility of generating and analysing hypotheses regarding disease distribution and causation. For example, GIS technology allows us to ask if a certain source of water (surface or groundwater) is responsible for gastrointestinal infections. Modern communication systems and data organisation and sharing methods, together with software development, allow information integration to assist epidemiology analysis.

The use of QMRA techniques are supplementing and according to Haas (2002), eventually will supplant, the use of indicator approaches in regulating the quality of drinking waters. Deposition and scour may play a significant role in water bodies in urban areas, especially after runoff events, when the counts of microorganisms are still high and exposure is most likely to occur.

An important question regards the potential extension of these observations to the public health area. If PCR seems to be a more reliable indicator of the occurrence of pathogens in drinking water than assessment of coliforms by plate counting, what should we do about it? Public health authorities worldwide are invested intellectually and financially in training and methodology for evaluation of water quality by plate counting for coliform bacterial counts. A major disadvantage of PCR, especially in developing countries, is the high cost of analysis per sample when it is used as a routine method. However, rapid results should allow us to identify contaminated water, treat it appropriately, and prevent disease, rather than focusing on curing it, which can translate into significant savings in healthcare costs and reduced morbidity and mortality for large numbers of infants, children and immunocompromised adults. When these factors are considered, high analysis costs are often offset by the benefits represented by reduced illness, reduced mortality, and lower overall health costs.

The particular area presented in this paper, which does not reflect the situation for the whole province of Salta, lacks a system able to provide safe water in a continuous operational mode. The DWP treats water from the irrigation channel, which is derived from the river, to produce drinking water. The irrigation channel does not contain water of the quality required for drinking water. The drinking water produced at the plant after treatment is not safe regarding the microbiological load detected (the water supply is in private hands and the lack of control by the government is evident).

The water stress in the area is a driving force to use water, intended for other applications, as irrigation, or from other sources, like groundwater. Water from the irrigation channel, which receives the impact of at least one farm, is sometimes used as drinking water by some of the temporary workers. Water from the channel is also used for washing laundry when the water supply at home is not adequate. On the other hand, groundwater supply comes from wells that are not deep enough – less than 10 m – to ensure the absence of microbial contamination. The characteristics of the soils are such that the impact of land use strongly affects shallow groundwater showing high nitrate (agriculture) and ammonia (farms) concentration, as well as high coliform counts, probably due to the closeness of septic tanks.

In summary, water management, water use and hygiene, factors that cannot be separated from water quality, together with the global health situation associated with poverty (malnutrition, accessibility to the health system, population settlements in areas without sanitary services and susceptible to flooding, etc.), contribute to the increase of diarrhoea cases and add complexity to the already compromised situation of the area. Water quality, as shown here, is not the main factor determining diarrhoea cases; however, monitoring the water quality will help to make decisions to prevent rather than to cure waterborne illnesses.

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