A broader approach to recreational water quality assessment: Buenos Aires City case study

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Abstract

In the last decade, the world population has become more urban than rural, but the human contact with nature is still a necessity for a proper physical and mental development. The urban green areas are a significant part of the urban heritage, providing fundamental ecosystem services. They give us the possibility of having social and cultural interaction surrounded by nature. Water is usually part of the landscape of these areas. The quality of the recreational water in urban green areas impacts on multiple factors like soil, vegetation, aquatic and terrestrial life and public health. A complete evaluation of this quality requires applying different methodologies simultaneously. Samples were collected at eight sites of Buenos Aires City in order to assess the quality of its recreational water. Results were compared with water quality standards in established legislation and were ranked by the National Sanitation Foundation Water Quality Index (NSF-WQI). Euphotic zone transparency was used as a parameter of the impact on aquatic life, measuring the Secchi depth. A test for fecal coliform bacteria was used as a risk indicator for human health. In accordance with the NSF-WQI ranking, the eight sampling sites have medium or bad water quality. Fifty percent of the sites exceeded the allowed count of coliform bacteria. According to established legislation, five of the studied sites were found to be unsuitable for primary, secondary or passive aquatic activities. Of the remaining sites, two were suitable for passive activities and only one qualified to be suitable for all kinds of aquatic activities. Secchi depth measures reveal a bad water quality for aquatic life at four of the analyzed sites.

Keywords Green urban areas · Recreational water · Water quality assessment · Water quality index

Introduction

More than 50% of the world population is currently living in urban areas. Due to the stressful city lifestyle, the possibilities of entertaining and rest in a natural environment are the most valued ecosystem services of the urban green areas, required for a life of good quality and important for public health (Bolund and Hunhammar 1999; Niemela et al. 2010). Many social, cultural and sportive activities in the city are performed thanks to the existence of this green infrastructure (McPhearson et al. 2014). However, as a result of overpopulation, the green spaces in the large cities are exposed to many negative impacts that affect the resilience of the urban environment and deteriorate its quality.

Water is usually part of the landscape of green urban areas. Aquatic ecosystems (rivers, lakes, groundwater, coastal waters and seas) support the delivery of crucial ecosystem services (Grizzetti et al. 2016). The analysis of recreational water quality is usually focused on the detection of bacteria. According to Wade et al. (2003), the association between this quality and human health outcomes has been studied for almost 70 years. Contact with water also exposes human health to diverse physical and chemical hazards (WHO 2003). The analysis of recreational water quality must take into consideration the health of bathers without leaving aside the rest of potential impacts of recreational water quality over the environment. Water quality has impacts on the entire local ecosystem: soil, vegetation, fish, birds, insects and other animals. It is fundamental for many of the biogeochemical processes of the ecosystem and determinant for the aesthetic landscape value of the area (González Castelain 2013).

Water quality is composed of multiple related variables. A change in one of them can affect the others. In some

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cases, these changes have a negative impact over several of the ecosystem services associated with water (Keeler et al. 2012). Monitoring this quality is important to obtain scientific information that functions as an indicator of the urban environment state.

This research is focused on the study of the quality of the recreational water at the main green urban areas of Buenos Aires City, Argentina. In order to apply a broader vision than public health to determine the quality of recreational water, several analytical methodologies were simultaneously used.

Methodology

The sampling period was from March 2015 to March 2017. Samples were collected on a seasonal basis, four times a year for each site. The parameters analyzed were pH, temperature, dissolved oxygen, 5-day biological oxygen demand, dissolved solids, nitrates, total phosphates, turbidity, transparency, fecal coliforms, arsenic and chromium VI. Results were compared with water quality standards established in national legislation and were ranked by the National Sanitation Foundation Water Quality Index (NSF-WQI). The transparency of the water was measured by a Secchi disk and used as an indicator of the impact on aquatic life.

Sample collection, stabilization, transportation and storage were made according to the Standard Methods for the Examination of Water and Wastewater (APHA 2012).

These measurements were made in situ with a portable meter: pH (S.M. 4500 B), electrical conductivity (Con) (S.M. 2510 B), and dissolved oxygen (DO) (S.M. 4500 O B). Transparency (Tr) of the water was semiquantitatively estimated with a Secchi disk (ISO 7027), and water temperature with an infrared thermometer (NIST Traceable, ISO 17025). Triplicate samples were taken into sterilized borosilicate glass bottles (S.M. 9060) of 500 mL each and

were transferred to the laboratory for further analysis. The samples were transported at 4 °C inside an isolated container using ice packs and gel packs. At the laboratory nitrates (NO_3^-) were determined by reduction of cadmium (S.M. 4500 NO_3^- E), phosphates (PO_4^{3-}) by ascorbic acid method (S.M. 4500 PO_4^{3-} E), chromium VI (Cr^{6+}) by diphenylcarbohydrazide method (ASTM D 1687 Test Method A), arsenic (As) by semiquantitative method, Gutzeit modified (Luong et al. 2007), 5-day biological oxygen demand (BOD5) by dilution method (S. M. 5210 B), turbidity (Tur) by formazin method (S.M. 2130 B), dissolved solids (DS) estimated by conductivity measurements (Carlson 2005), and fecal coliforms (FC) by multiple tube fermentation technique (S.M. 9221 E). The temperature change of the water (ΔT) was calculated with respect to the average value of the surface waters temperature in the Metropolitan Area of Buenos Aires (AMBA) region. According to the Environmental Atlas of Buenos Aires (2010), the annual mean value is 20 °C. The water quality was rated by NSF-WQI calculation, was compared with established regulations based on international water quality standards and with Secchi depth recommendations. Table 1 summarizes the parameters analyzed and the used methods.

The NSF-WQI was developed in 1970 with the objective of providing a tool for evaluating water quality.

This index was selected because is one of the most frequently used for water quality assessment across the world (Lumb et al. 2011; Poonam et al. 2013) and it has great credibility since more than a hundred experts contributed to its development (Sutadian et al. 2016). The index allows studying the evolution of water quality for a specific site in a timeline, or for different sites of the same body of water at a given time in a reproducible way (Phadatare and Gawande 2016). It also allows a standardized comparison between different bodies of water. (Brown et al. 1970; Poonam et al. 2013).

Table 1 Parameters analyzed

Water quality parameter	Method
pH	Portable meter, Standard Methods 4500 B
Electrical conductivity	Portable meter, Standard Methods 2510 B
Dissolved oxygen	Portable meter, Standard Methods 4500 O B
Transparency. Secchi depth	Secchi disk, ISO 7027
Temperature	Infrared thermometer NIST Traceable, ISO 17025
Nitrates	Reduction of cadmium, Standard Method 4500 NO_3^- E
Phosphates	Ascorbic acid method, Standar Method 4500 PO_4^{3-} E
Chromium VI	Diphenylcarbohydrazide method, ASTM D 1687 Test Method A
Arsenic	Semiquantitative method, Gutzeit modified
5-day biological oxygen demand	Dilution method, Standard Method 5210 B
Turbidity	Formazin method, Standard Method 2130 B
Dissolved solids	Estimated by conductivity measurements
Fecal coliforms	Multiple tube fermentation technique, standard method 9221 E

Table 2 NSF-WQI (weight of the parameters)

Factors	DO	FC	pH	BOD	ΔT	PO_4^{3-}	NO_3^-	Tur	DS
W_i	0.17	0.16	0.11	0.11	0.10	0.10	0.10	0.08	0.07

The NSF-WQI is based on nine parameters selected by Delphi method. A subindex Q_i is obtained for each parameter introducing the experimental value into the respective rating curve (Tyagi et al. 2013). Each parameter has been assigned a weight, as seen in Table 2. The index is calculated as a weighted average, in accordance with the equation:

$$WQI = \sum_{i=1}^n W_i * Q_i$$

Its score ranges from 0 to 100, with 100 being the maximum score. According to the score, the NSF-WQI determines the status of the water body into five categories, namely excellent (91 to 100), good (71 to 90), medium (51 to 70), bad (26 to 50) and very bad (0 to 25) (Alexakis et al. 2016).

The obtained data were also compared with the parametric standard values proposed in the regulation issued by the Water Resources Secretariat of the Ministry of Interior (SSRH). This regulation defines the values associated with each category of use of the water, according to Tables 3 and 4 (Ministerio del Interior 2003).

In relation to public health, the fecal coliforms are accepted as fecal indicator bacteria, because they are more easily measured than other pathogens and more abundant in fecal material. This increases the likelihood of detection (Griffith et al. 2016).

Arsenic and hexavalent chromium are other important pollutants to consider when studying the water quality in relation to human health. The analysis of arsenic levels in Argentina is important because its frequent presence is responsible for chronic endemic regional hydroarsenicism (HACRE). In many regions of the country, including certain areas of Buenos Aires, the concentration of arsenic exceeds the level of 10 $\mu\text{g/L}$ admitted by the World Health Organization (Litter 2010). The high degree of industrialization along the coast of the Río de la Plata generates a chromium hexavalent input (Licursi and Gomez 2013). According to Rocchetta et al. (2007), this pollutant is also present in the Riachuelo waters and the main discharge comes from tanning industry. Certain chromium hexavalent compounds are carcinogenic in humans. It can cause a wide range of other health effects such as allergic reactions, ulcers, liver damage, convulsions or even death. (Pellerin and Booker 2000).

Photosynthesis is possible only within a thin layer of the superficial waters in which at least 1% of the photosynthetically active radiation can penetrate. This zone is referred as euphotic depth. A simple way to assess the penetration of

Table 3 Uses of the water

Category	Use: water suitable for...
I	Human consumption after conventional treatment
II	Recreational activity with direct contact (primary)
III	Recreational activity without direct contact (secondary)
IV	Passive recreational activities (aesthetic enjoyment)
V	Preservation of aquatic life with prolonged exposure
VI	Preservation of aquatic life without prolonged exposure

light into water is by using a Secchi disk (Padial and Thomaz 2008; Luhtala and Tolvanen 2013). Water absorbs or scatters light due to different factors like the color of the water, the presence of phytoplankton and presence of erosional materials suspended (Lee et al. 1995). The optimum Secchi depth for fish at lakes and lagoons varies in relation to the species of fish and the causes of the turbidity. According to Bhatnagar and Devi (2013), a range from 30 to 80 cm is good for fish health. Low transparency of the water causes fish stress. The Food and Agriculture Organization of the United Nations (FAO 2005) recommends a range from 40 to 60 cm. A value less than 40 cm indicates the presence of an amount of plankton that endangers the survival of the fish during the night when there is no production of oxygen due to photosynthesis but respiration of plankton increases consumption. A transparency greater than 60 cm indicates low amounts of plankton and the fish may not have enough natural food.

The city and the sampling sites

The Autonomous City of Buenos Aires, known by the acronym CABA, is the capital city of Argentina. It has an area of 203.3 km^2 (78.5 square miles) and according to the last national census, it has 2.89 million inhabitants. Buenos Aires is surrounded by an urban cluster known as Great Buenos Aires (GBA). This urban conglomerate is one of the largest in the southern hemisphere. The urban zone formed by GBA and CABA is called the Metropolitan Area of Buenos Aires (AMBA) and has an area of 2681 km^2 (1035 square miles). According to the census of 2010, the population estimate is 14.28 million inhabitants and the population density is 5.3 thousand people per km^2 (13.8 thousand people per square mile). Buenos Aires AMBA is at the 21st place among the 1000 most populated cities in the world (Demographia 2017). It is estimated that 12% of the GBA inhabitants enter

Table 4 Standard values of the analyzed parameters associated with each category of use

	I	II	III	IV	V	VI
DO (mg/L)	> 4	> 5	> 5	> 2	> 5	> 3
BOD5 (mg/L)	< 5	< 3	< 10	< 15	< 3	< 10
NO ₃ ⁻ (mg/L)	< 10	< 10	< 10	NR	NR	NR
PO ₄ ³⁻ (mg/L)	NR	< 1	< 1	< 5	< 10	< 100
Cr ⁶ (μg/L)	< 50	< 50	NR	NR	< 2	< 20
As (μg/L)	< 50	< 50	NR	NR	< 150	< 340
pH	6–9	6–9	6–9	6–9	6–9	4–10.5
Temp (°C)	NR	15–35	15–35	< 35	ΔT < 3	ΔT < 3
FC (MPN/100 mL)	< 2000	< 200	< 20,000	NR	NR	NR

NR: with no restriction

Fig. 1 Map of Buenos Aires City and the sampling sites (Mapoteca Educar)

into CABA daily for work, study or for other reasons (Diario Clarín 2013). The city has 1055 green spaces that cover an area of 1924.5 ha (7.43 square miles). The relationship between this area and the population indicates that it corresponds to 6.3 m² of green space per inhabitant (9765 square inches per capita) (Buenos Aires Ciudad 2017a).

Water is an important presence in the green spaces of Buenos Aires City. The east city limit is the Río de la Plata coast, surrounded by “La Costanera,” an area of walks along the river. The south city limit is the Riachuelo (formerly Matanza River). Next to it, “Caminito,” a picturesque tango corner of the city and a favorite place for tourists. The city also has another 19 important green urban areas of which 14 have ponds and lakes, where citizens and tourists run, walk, row and relax.

To assess the quality of the recreational water in Buenos Aires City, samples were collected at eight sites on the main green areas of the city. The sampling sites are marked over the map as shown in Fig. 1.

The description of the sampling sites and the activities performed in every location are shown in Table 5.

Results and discussion

Table 6 summarizes the results obtained for the different parameters analyzed. Due to the minimum seasonal variation observed, the values presented in this study correspond to the average result for each sampling site.

Table 7 shows the subindex (Q_i) for the nine parameters (factors) required by the NSF-WQI, obtained by transferring each parameter value to the corresponding rating curve.

Table 8 shows the results for the NSF-WQI at each sampling site.

In accordance to the NSF-WQI ranking, the eight sampling sites have bad or medium water quality.

In the sites covered by this study, people engage in outdoor activities such as sporting or recreational rowing, biking, skating, running and walking around the water. Comparing the obtained results with the regulations of the SSRH, as seen in Table 9, sampling site #1 allows primary, secondary and passive recreational uses of the water, and sampling sites #2 and #6 only admits passive recreational activities. The

Table 5 Description of the sampling sites

Location	Size/area	Description	Activities
#1 Parque Centenario Pond	Pond area: 1 ha or 2.47 acres 1.6 m or 5.25 ft	Artificial pond. The water comes from channeled natural springs, rain and a permanent pumping system	In this park, different cultural events and sport trainings are held. People do recreational rowing at the pond
#2 Lugano Lake, Ecological Reserve of Parque Roca	The lake has 550 m (601.5 yds.) in diameter	This artificial lake was built in 1940 to act as a relief for Stream Cildañez, avoiding the overflows of the Riachuelo	During summer, the city government develops by the lake the “Buenos Aires Playa Program,” installing artificial sand beaches with umbrellas, lounge chairs, showers and organizing different sports and activities for families
#3 Riachuelo (formerly named Matanza River)	This is the main river of the Riachuelo Basin. The basin is 64 km (39.76 mi) long and 35 km (21.75 mi) wide	The region is inhabited by four million people and is one of the four most polluted watersheds in South America. The samples were taken at the mouth of the Riachuelo, toward the Río de la Plata	Rowing activities are organized periodically in these waters. At the riverside, “Caminito” is one of the favorite tourist places in Buenos Aires
#4 Puerto Madero	The district covers 140 ha (346 acres)	This is one of the most exclusive and expensive neighborhoods in the city, built at the Río de la Plata riverbank, in the facilities of the old port	The district constitutes an important residential, business, gastronomic and recreational center of the city. The practice of rowing is usual at the old port dikes
#5 Ecological Reserve of Costanera Sur	The reserve has a surface of 350 ha (865 acres) covered with forest, wetlands and lagoons	Located on the south riverbank of the Río de la Plata, this ecological reserve is a world designated Ramsar Site, according to the Convention on Wetlands	In this reserve lives more than 307 species of birds and 575 species of plants, small animals, insects and variety of aquatic life. Every weekend the reserve is visited by more than 15 thousand people
#6 Planetarium Lake	This lake has an area of 9 thousand m ² (2.22 acres)	This is one of the most representative views of the Tres de Febrero Park, more known as Palermo Forests, in the heart of Buenos Aires City	It is visited by more than 60 thousand people every weekend. On this park, it is possible to rent boats and canoes for recreational purposes
#7 Plaza Holanda Lake	Also known as Lago del Rosedal it has an area of 47 thousand m ² (11.61 acres)	This is one of the most popular attractions of the Tres de Febrero Park	People perform multiple social and cultural activities in the park. Recreational rowing is practiced on the lake
#8 Regatas Lake	It has a perimeter of 2 thousand m (2187 yd.)	This lake is the favorite of sportsmen	There is a golf court beside the lake, and around its perimeter there is a very popular track for runners

Revista Horizonte (2016), Buenos Aires Ciudad (2017b, c, d), Watkins (2013), Corporación Puerto Madero (2017), La Nación (2015)

Table 6 Parameters values for each sampling site

Sampling site	# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8
DO (mg/L)	11.6	5.25	1.5	6.8	2.8	4.3	5.6	4.3
BOD ₅ (mg/L)	< 5	< 5	48.7	< 5	41.4	6.8	9.5	1.5
NO ₃ ⁻ (mg/L)	< 10	1	< 10	< 5	< 10	< 10	< 10	< 10
PO ₄ ³⁻ (mg/L)	< 1	5	< 1	< 1	< 1	< 1	1.5	< 1
Cr ⁶⁺ (μg/L)	28	0	29	14	0	51	57	110
As (μg/L)	40	20	100	0	20	0	0	0
pH	6	6	7.5	5	5	9.6	10	6.7
ΔT (°C)	1.3	2.4	1.7	1.7	2.5	2.8	3.7	4
FC (MPN/100 mL)	< 3	460	110,000	9300	43	2	1100	4
Tur (NTU)	20	36	34	18	40	6	18	5
DS (mg/L)	171	665	463	408	313	203	936	156
Con (μS/cm)	342	1331	927	817	626	405	1873	313
Tr (cm)	40	24	26.5	46.5	22	18.5	47.5	58.5

Table 7 Value of the subindex Q_i for each factor

Factors	#1	#2	#3	#4	#5	#6	#7	#8
FC	86	29	2	10	54	91	22	82
DS	76	20	38	45	58	72	20	78
DO	92	56	11	87	19	41	60	41
pH	55	55	93	27	27	29	20	79
Tur	61	48	50	63	45	84	63	86
BOD	56	56	5	56	5	47	36	90
NO ₃ ⁻	51	96	51	65	51	51	51	51
PO ₄ ³⁻	40	13	40	40	40	40	31	40
ΔT	88	83	86	86	83	82	78	77

Table 8 NSF-WQI results for the sampling sites

Sampling site	#1	#2	#3	#4	#5	#6	#7	#8
WQI	70	51	37	53	42	59	42	68

Table 9 Possible water uses at the sampling sites

Sampling site	Cat. I	Cat. II	Cat. III	Cat. IV	Cat. V	Cat. VI
#1	✓	✓	✓	✓	×	×
#2	✓	×	×	✓	×	✓
#3	×	×	×	×	×	×
#4	×	×	×	×	×	✓
#5	×	×	×	×	×	×
#6	×	×	×	✓	×	×
#7	×	×	×	×	×	✓
#8	×	×	×	×	×	×

water quality of the other five sampling sites does not meet the requirements of the SSRH regulations for the performance of recreational activities.

Secchi disk depth is less than 30 cm in sampling sites #2, #3, #5 and #6 (see Table 3). The low transparency on these sites may cause stress to some fish species.

The explanation of the presence of Cr⁶⁺ and the elevated fecal coliform count in some of the lakes that do not receive directly sewage or industrial effluents can be found by the analysis of the hydrological setting of the city. Under Buenos Aires run several piped streams. The most important of them are Medrano stream, Vega stream, Maldonado stream and

Table 10 Summary of results

Sampling site	NSF-WQI quality	Use as recreational waters	Presence of Cr ⁶⁺	Presence of As	Secchi depth
#1	Medium	Primary, secondary, passive activities	+	+	Suitable for fish
#2	Medium	Only passive activities	–	+	Fish stress
#3	Bad	None	+	+	Fish stress
#4	Medium	None	+	–	Suitable for fish
#5	Bad	None	–	+	Fish stress
#6	Medium	Only passive activities	+	–	Fish stress
#7	Bad	None	+	–	Suitable for fish
#8	Medium	None	+	–	Suitable for fish

Radio Antiguo Basin (see Fig. 1). These streams were channeled to prevent city floods. All of them are connected to the highly contaminated Río de la Plata. The waters of this river are polluted due to the dumping of effluents from different sources without a correct treatment. These wastewaters come from the two main cities of the country: Buenos Aires and La Plata (Colombo et al. 1989). The presence of strong winds from the south-southeast quadrant coinciding with the axis of the river is a common meteorological phenomenon known as Sudestada. This wind drags on the waters of the river, which produces the increase in the level of the waters on the coast of Buenos Aires. According to the National Meteorological Service (SMN 2000), it makes difficult the drainage of smaller channels and brings the Riachuelo waters up to the city. This indirect contact with the Río de la Plata, polluted by the Riachuelo waters, through the piped streams can explain the level of contamination with Cr⁶⁺ of the ornamental lakes on sampling sites #1, #6, #7 and #8.

Table 10 shows a summary of results for each sampling site. Sampling site #1 has the best water quality status, according to the ranking of the NSF. The explanation of this result may be related to the origin of the water. This pond is connected to several natural springs but its level is also maintained thanks to a clean water pumping system. The stream Cildañez connects the Riachuelo with sampling site #2 (Lago Lugano) to prevent floods over the city. This connection with the fourth most polluted watershed in South America explains the poor water quality of the lake. Sampling site #3 is at the Riachuelo riverside and has the poorest quality of all the sites analyzed. The pollution of this river is one of the biggest environmental issues of Buenos Aires. The lack of planning for land use, with no urban planning nor sanitation infrastructure, and the disorderly location of industries are some of the historical causes of the pollution of this basin. Its remediation represents a challenge that different governments have not yet been able to solve (Faggi et al. 2015). Sampling sites

#4 and #5 are on the Río de la Plata riverside. The results reflect the serious environmental status of this river. Sampling sites #6, #7 and #8 are located in a park at one of the most beautiful, important and elegant neighborhoods of the city. These lakes are connected to the channeled stream Vega. This connection and the periodical occurrence of the Sudestada phenomenon explain the low quality of its waters and the presence of Cr⁶⁺, a clearly industrial pollutant.

Conclusion

The study of recreational water quality with a broad point of view than public health allows identifying potential risks over the different environmental components of the urban green areas. To prevent the deterioration of the ecosystem services provided by these areas, the city government must consider including the monitoring, improvement and maintenance of the quality of the recreational water of the city in its public policies. As an outcome of this study, recommendations for the implementation of protection tasks, as well as the promotion of a law stating the sanitary and environmental emergency of the studied areas were given to the city government.

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References

- Alexakis D, Tsihrintzis VA, Tsakiris G, Gikas GD (2016) Suitability of water quality indices for application in lakes in the Mediterranean. *Water Resour Manag* 30(5):1621–1633
- APHA (2012) Standard methods for the examination of water and wastewater. American Public Health Association, Washington, DC
- ASTM (1992) Manual of Water and Environmental Technology. D 1687-92. Diphenylcarbohydrazide method
- Atlas Ambiental de Buenos Aires (2010) Río. Aguas. Propiedades del agua. Temperatura. http://www.atlasdebuenosaires.gov.ar/aaba/index.php?option=com_content&task=view&id=318&Itemid=184. Accessed 30 Nov 2017
- Bhatnagar A, Devi P (2013) Water quality guidelines for the management of pond fish culture. *Int J Environ Sci* 3(6):1980
- Bolund P, Hunhammar S (1999) Ecosystem services in urban areas. *Ecol Econ* 29(2):293–301
- Brown RM, McClelland NI, Deininger RA, Tozer RZ (1970) A water quality index-do we dare? *Water Sewage Works* 117:339–343
- Buenos Aires Ciudad (2017a) Ciudad de Buenos Aires. <http://www.buenosaires.gov.ar/laciudad/ciudad>. Accessed 10 Nov 2017
- Buenos Aires Ciudad (2017b) Vení a conocer el Parque Natural Lago Lugano. <http://www.buenosaires.gov.ar/agenciaambiental/veniconocer-el-parque-natural-lago-lugano>. Accessed 08 Nov 2017
- Buenos Aires Ciudad (2017c) Reserva Ecológica. <http://www.buenosaires.gov.ar/ciudadverde/espaciosverdes/reservaecologica>. Accessed 16 Nov 2017
- Buenos Aires Ciudad (2017d) Los lagos. <http://www.buenosaires.gov.ar/ciudadverde/espaciosverdes/parquetresdefebrero/los-lagos>. Accessed on 16 Nov 2017
- Carlson G (2005) Total dissolved solids from conductivity. Technical Note In Situ Inc, 14
- Colombo JC, Pelletier E, Brochu C, Khalil M, Catoggio JA (1989) Determination of hydrocarbon sources using n-alkane and polycyclic aromatic hydrocarbon distribution indexes. Case study: Río de la Plata estuary, Argentina. *Environ Sci Technol* 23(7):888–894
- CPM (2017) Puerto Madero. Official Puerto Madero website. <http://www.puertomadero.com/#/es/puertomadero>. Accessed 16 Nov 2017
- Demographia (2017) World Urban Areas. 13th Annual Edition: 2017: 04 <http://www.demographia.com/db-worldua.pdf>. Accessed 10 Nov 2017
- Diario Clarín (2013) Casi la mitad de quienes trabajan en Capital llega desde el GBA. https://www.clarin.com/sociedad/mitad-trabajan-Capital-llega-GBA_0_SJOz-EjwXe.html. Accessed 10 Nov 2017
- Faggi A, Breuste J, Malignani E, Johnson BG (2015) Estado y percepción de los servicios ecosistémicos de las riberas del Matanza-Riachuelo. *Eur Sci J ESJ* 11(10):296–305
- Food and Agricultural Organization of the United Nations (2005) Mejora de la calidad de agua en los estanques. http://www.fao.org/fishery/static/FAO_Training/FAO_Training/General/x6709s/x6709s02.htm. Accessed 13 Mar 2018
- González Castelain J (2013) Ecohidrología: el agua y los procesos ecosistémicos. <https://www.unicen.edu.ar/content/ecohidrologia%20AD-el-agua-y-los-procesos-ecosist%C3%A9micos>. Accessed 10 Mar 2018
- Griffith JF, Weisberg SB, Arnold BF, Cao Y, Schiff KC, Colford JM Jr (2016) Epidemiologic evaluation of multiple alternate microbial water quality monitoring indicators at three California beaches. *Water Res* 94:371–381
- Grizzetti B, Lanzanova D, Lique C, Reynaud A, Cardoso AC (2016) Assessing water ecosystem services for water resource management. *Environ Sci Policy* 61:194–203
- ISO (1990) ISO 7027. Water quality. Determination of turbidity. International Standards Organization, Geneva
- ISO (2005) ISO 17025 General requirements for the competence of testing and calibration laboratories. ISO, Geneva
- ISO (2017) ISO/DIS 7027-2 (en). Water quality. Determination of turbidity. Semi-quantitative method for the assessment of transparency of waters. Chapter 5.1
- Keeler BL, Polasky S, Brauman KA, Johnson KA, Finlay JC, O'Neill A et al (2012) Linking water quality and well-being for improved assessment and valuation of ecosystem services. *Proc Natl Acad Sci* 109(45):18619–18624
- La Nación (2015) Parques Porteños: cada semana van 130000 personas. <https://www.lanacion.com.ar/1809450-parques-portenos-cada-fin-de-semana-van-130-mil-personas>. Accessed 16 Nov 2017
- Lee GF, Jones-Lee A, Rast W (1995) Secchi depth as a water quality parameter. Report of G. Fred Lee & Associates. <http://www.gfredlee.com/secchi.html>. Accessed 22 Nov 2017
- Licursi M, Gomez N (2013) Short-term toxicity of hexavalent-chromium to epipsammic diatoms of a microtidal estuary (Río de la Plata): responses from the individual cell to the community structure. *Aquat Toxicol* 134:82–91
- Litter MI (2010) The problem of arsenic in Argentina. *Rev SAEGR* 17:5–10
- Luhtala H, Tolvanen H (2013) Optimizing the use of Secchi depth as a proxy for euphotic depth in coastal waters: an empirical study from the Baltic Sea. *ISPRS Int J Geo Inf* 2(4):1153–1168
- Lumb A, Sharma TC, Bibeault JF (2011) A review of genesis and evolution of water quality index (WQI) and some future directions. *Water Qual Expo Health* 3(1):11–24
- Luong JHT, Majid E, Male KB (2007) Analytical tools for monitoring arsenic in the environment. *Open Anal Chem J* 1(1):7–14
- McPhearson T, Hamstead ZA, Kremer P (2014) Urban ecosystem services for resilience planning and management in New York City. *Ambio* 43(4):502–515. <https://doi.org/10.1007/s13280-014-0509-8>
- Ministerio de Educación. Presidencia de la Nación. (n.d.) Atlas interactivo. Ciudad de Buenos Aires, mapa físico. <http://mapoteca.educ.ar/files/index.html.1.5.html>. Accessed on 08 Nov 2017
- Ministerio del Interior, obras públicas y vivienda. Presidencia de la Nación. Subsecretaría de Recursos Hídricos (2003) Anexo: Criterios utilizados para la definición de los valores asociados a cada zona de uso. <http://www.acumar.gov.ar/ACUsentencias/CausaMendoza/2009abril/060409e/AnexoIusos060409.pdf>. Accessed 22 July 2017
- Niemela J et al (2010) Using the ecosystem services approach for better planning and conservation of urban green spaces: a Finland case study. *Biodivers Conserv* 19:3225–3243. <https://doi.org/10.1007/s10531-010-9888-8>
- Padial AA, Thomaz SM (2008) Prediction of the light attenuation coefficient through the Secchi disk depth: empirical modeling in two large Neotropical ecosystems. *Limnology* 9(2):143–151
- Pellerin C, Booker SM (2000) Reflections on hexavalent chromium: health hazards of an industrial heavyweight. *Environ Health Perspect* 108(9):A402
- Phadatare S, Gawande S (2016) Review paper on development of water quality index. *Int J Eng* 5(05):765–767
- Poonam T, Tanushree B, Sukalyan C (2013) Water quality indices-important tools for water quality assessment: a review. *Int J Adv Chem* 1(1):15–28
- Revista Horizonte (2016) Caballito te quiero. Parques y Plazas. Parque Centenario. <http://caballitotequiero.com.ar/portal/portfolio-item/parque-centenario/>. Accessed 08 Nov 2017
- Rocchetta I, Leonardi PI, Amado Filho GM, del Carmen Ríos de Molina M, Conforti V (2007) Ultrastructure and X-ray microanalysis of *Euglena gracilis* (Euglenophyta) under chromium stress. *Phycologia* 46(3):300–306

- SMN (2000) Sudestada. <http://www.smn.gov.ar/?mod=biblioteca&id=71>. Accessed 01 Dec 2017
- Sutadian AD, Muttill N, Yilmaz AG, Perera BJC (2016) Development of river water quality indices—a review. *Environ Monit Assess* 188(1):58
- Tyagi S, Sharma B, Singh P, Dobhal R (2013) Water quality assessment in terms of water quality index. *Am J Water Resour* 1(3):34–38
- Wade TJ, Pai N, Eisenberg JN, Colford JM Jr (2003) Do US environmental protection agency water quality guidelines for recreational waters prevent gastrointestinal illness? A systematic review and meta-analysis. *Environ Health Perspect* 111(8):1102
- Watkins K (2013) Las cuatro cuencas hidrográficas más contaminadas de Sudamérica. BN Américas. <https://www.bnamericas.com/es/reportajes/aguasyresiduos/las-cuatro-cuencas-hidrograficas-mas-contaminadas-de-sudamerica>. Accessed 16 Nov 2017
- WHO (2003) Healthy recreational waters. <http://www.who.int/featu res/2003/10/en/>. Accessed 02 Dec 2017

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