Rev. Mus. Argentino Cienc. Nat., n.s.
2(2): 123-130, 2000
Buenos Aires, ISSN 1514-5158

Impact of the Morón stream on water quality of the Reconquista River (Buenos Aires, Argentina)

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Abstract: The Reconquista River basin is located in an urban area where 2.5 10^6 inhabitants and 4,242 industries are settled. The confluence with the Morón stream shows the largest anthropogenic impact. The effect of the Morón stream on the water quality of the Reconquista River was evaluated in relation to its organic, mineral and metal contribution. Bimonthly samplings were carried out in the Reconquista River upstream (GOR), and downstream (SMT) from the confluence with the Morón stream and in the latter (MOR). Dissolved oxygen, pH, conductivity, temperature, transparency, nutrients, major ions, suspended solids, particulate and total organic carbon, Kjeldahl nitrogen, total phosphorus and heavy metals were determined in water samples. Discharge ratios between the Reconquista and Morón streams were estimated based on chloride concentrations. The samplings were ordered from the Principal Component Analysis in: GOR, SMT and MOR according to a growing gradient of organic and mineral contamination. This gradient has a spatial component (related to the discharge point of the Morón stream) and one related with the flow of the Reconquista River. Mean levels of heavy metals were higher than the thresholds for aquatic life protection. The most important were: lead, zinc, copper and mainly chromium, all of them related to industrial activity. Their concentrations responded to an irregular and intermittent discharge. Sometimes, metal levels at SMT and GOR were higher than at MOR, indicating other sources of contamination besides the Morón stream.

Key words: heavy metals, Morón stream, organic contamination, Reconquista River, urban river, water quality

The Reconquista River basin has a surface of 1.67 10^5 hectares 72,000 are occupied by agricultural areas, mainly located in the upper basin, and 95,000 are urbanized, mostly located in the middle and lower basin. The discharge in the study area ranges from 86,362 to 143,591 m^3 day^{-1} (Thames Water Consultancy Service, 1979) in agreement with the precipitation pattern. The basin comprises 14 districts with more than 2.5 10^6 inhabitants, that represent 8% of the Argentine population (Saltiel, 1997a). Olson *et al.* (1998) consider that the Reconquista basin is comprised within a critical area with regard to the conservation status of freshwater ecoregions of Latin America. The main course and its tributaries receive running waters from landfills and cultivated lands as well as domestic and industrial effluents (from food, textile, rubber, chemical industries, and tanneries). Thus, there is a large contribution of organic matter and pollutants as heavy metals among others (Castañé *et al.*, 1998; García *et al.*, 1998), that determine a high to very high degree of contamination in the middle and low basin (Arreghini *et al.*, 1997).

The largest population in the basin concentrates in Tres de Febrero, San Martín, Morón and ex Gral Sarmiento districts. The mean density for the whole basin is 36.4 inhabitants $hectare^{-1}$, reaching 88.5 inhabitants $hectare^{-1}$ in San Martín. Only 16% of the population of the basin has sewers, and 37% has potable water (Saltiel, 1997b). The biggest spillage of industrial effluents are located in San Martín, Morón, ex Gral. Sarmiento and Tres de Febrero districts, mainly corresponding to rubber, textile, mechanics and food industries (Pescuma & Guaresti, 1992) (Table 1). In the nine more polluted districts, the total number of industries with polluting potential is 4,242 which produce an organic load equivalent to a population of 2,467,866 inhabitants, similar to

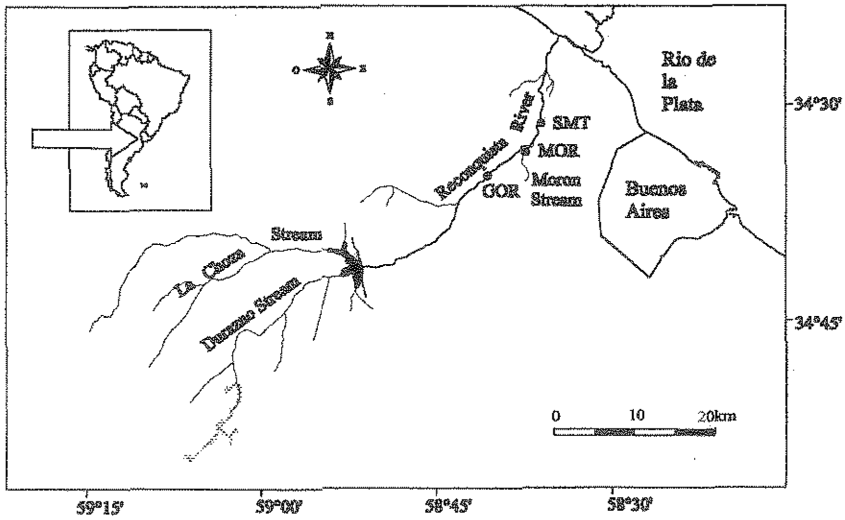

Fig. 1. Area of study (● sampling sites)

Table 1. Industrial activities of the area (Data obtained from Pescuma & Guaresti, 1992).

	Volume of spilled effluents (m³ day⁻¹)	
	in Reconquista River*	in Morón stream
Cattle slaughter, meats	925	1.712
Milk and derivatives	-	167
Cereals, flower and derivatives	1	-
Alcohol and alcoholic beverages	1.029	71
Other foods	-	2.387
Textile	988	4.707
Hides and skins	-	1.993
Cellulose, paper and graphical material	3	1.323
Rubber	8.472	3.097
Chemicals	441	369
Cement and stones	-	38
Shipyards and mechanic workshops	-	3.126
Steel metallurgy	95	521
Electrical apparatus and material	142	41
Metallurgy	48	275
Ice factory	74	-
Photographic articles and related material	-	5
Various manufactures	20	295
Car wash (cattle trucks excluded)	80	-
Non industrial facilities	1.165	-
Laundry	36	-
Total	13.519	20.127

* Considering only San Martín, Tres de Febrero, Morón and ex Gral. Sarmiento districts.

the total population of the basin (AGOSBA, 1991).

The Morón stream flows through Tres de Febrero, Morón and San Martín districts until its confluence with the Reconquista River, 17 km upstream from the mouth of the latter. Kuczynski (1994) analyzed some physical, chemical and microbiological variables during the decade of the 80s, and recorded extremely high organic and bacterial loads (COD=703 mg l^{-1} and coliforms were occasionally higher than a million and a half ind l^{-1}). At low flow conditions, the Morón discharges are 52,000 m^3 day^{-1} (Thames Water Consultancy Service, 1979), depending on both precipitation and spilled effluents. Its longitude is roughly 16 km, of which the upper 4.5 km are tubed.

The objective of the present study is to assess the impact of the Morón stream on the water quality of the Reconquista River in relation to organic and heavy metal contamination.

MATERIALS AND METHODS

Surface water samples were taken at three sites: Gorriti (GOR), and San Martín (SMT), on the Reconquista River located 18 km upstream and 1 km downstream respectively from the confluence with the Morón stream, and the Morón stream (MOR) at the bridge of Route 8 (Fig. 1). Five samplings were carried out in June, August, October and December 1996 and February 1997.

Dissolved oxygen (DO), pH, conductivity, temperature and transparency (Secchi depth) were determined *in situ*. Water samples were filtered through Whatman GF/C filters, and carried in ice to the laboratory. Dissolved nutrients were determined in the filtrate. Soluble reactive phosphorus (SRP) (molybdate-ascorbic), nitrates ($N\text{-}NO_3^-$) (reduction with hydrazine sulfate), nitrites ($N\text{-}NO_2^-$) (diazotation) were determined after Strickland & Parsons (1968). Ammonium ($N\text{-}NH_4^+$) (indophenol blue) was measured according to Mackereth *et al.*, (1978). Calcium (Ca^{2+}) and magnesium (Mg^{2+}) (EDTA titration), sodium (Na^+) and potassium (K^+) (flame photometry), bicarbonate (HCO_3^-) (Gran titration), sulfate (SO_4^{2-}) (turbidimetry) and chloride (Cl^-) (silver nitrate titration) were determined following APHA (1992). Dissolved inorganic nitrogen (DIN) was calculated as the sum of ammonium, nitrates and nitrites. Suspended matter (SM) was determined as the weight difference after filtration. Particulate organic matter (POC) was determined after Golterman *et al*. (1978) previous digestion of the filters used for SM determination. Total organic carbon (TOC) (Golterman *et al*, 1978), Kjeldahl nitrogen (NKj) and total phosphorus (TP) (APHA, 1992) were determined in unfiltered water samples fixed in the field with sulfuric acid.

The mean concentration of Kjeldahl nitrogen, ammonium, total phosphorus, soluble reactive phosphorus and discharge were used to estimate the daily loads at each sampling site. At low flow, discharge values estimated were 86,362 and 143,591 m^3 day^{-1} in the Reconquista River near GOR and downstream from the confluence, respectively, and 52,000 m^3 day^{-1} in the Morón stream (Thames Water Consultancy Service, 1979). The Morón value corresponded to a daily discharge average, and the rest was estimated from a mathematical model.

Total concentrations of metals (manganese, iron, copper, chromium, zinc, cadmium and lead) were performed according to APHA (1992) in unfiltered water samples fixed in the field with nitric acid. The determinations were carried out by inductive coupling plasm atomic emission spectrophotometer (ICPAES).

The water quality index (ICA, Berón, 1984) was calculated in each site and sampling date, considering dissolved oxygen, percentage of oxygen saturation, ammonium, chlorides and temperature. The correlations were carried out using the Spearman correlation index. The Kruskal-Wallis test was used to compare the observations between sites and sampling dates for each variable, and when significant differences were obtained, analysis of multiple comparisons was applied (Daniel, 1978). Principal Component Analysis (PCA) was carried out on the correlation matrix of the variables: dissolved oxygen, Kjeldahl nitrogen, ammonium, nitrate, nitrite, total phosphorus, particulate organic carbon, total organic carbon, calcium, magnesium, sodium, potassium, bicarbonate, sulphate and chloride. Only those components leading to clear conclusions and accounting for more than 10% of total variance were considered (Pla, 1986).

RESULTS

The relative discharge at SMT with regard to MOR (Table 2), was obtained from the general dilution equation (Jolánkai, 1997): $(Q_{Gor}*Cl^-_{Gor})+(Q_{Mor}*Cl^-_{Mor})=(Q_{Gor}+Q_{Mor})*Cl^-_{SMT}$, considering $Q_{SMT}=Q_{Gor}+Q_{Mor}$.

Such an approach assumes steady state conditions in the water courses and instantaneous full cross-sectional mixing, and

Table 2. Relative discharge of Reconquista River at SMT.

June	$Q_{SMT}= 2.579\ Q_{MOR}$
August	$Q_{SMT}= 2.544\ Q_{MOR}$
October	$Q_{SMT}= 2.935\ Q_{MOR}$
December	$Q_{SMT}= 1.637\ Q_{MOR}$
February	$Q_{SMT}= 5.203\ Q_{MOR}$

relies on chloride behaviour as a conservative and mobile ion.

The concentration of dissolved oxygen (Table 3) differed significantly among sites ($p<0.05$) and average values at SMT were 18 times lower than at GOR, becoming occasionally anoxic at SMT (June and December). MOR showed values of dissolved oxygen ranging from 0.1 to 0.6 mg l^{-1}, the maximum being attained in coincidence with the lowest temperature (June). The temperature did not differ significantly among sites, and it followed a seasonal behavior, excluding thermal contamination. Water pH was alkaline.

Conductivity (Table 3) showed significant differences among sites ($p<0.001$), the higher values being in MOR, (June and February). In February the conductivity at MOR was very high (3,090 $\mu S\ cm^{-1}$). However, at SMT the conductivity was approximately the same as at GOR. The highest relative discharge at SMT with regard to MOR was obtained in February (Table 2).

Secchi depth (Table 3) diminished 38% and the suspended matter increased 130% at SMT with regard to GOR, presenting a significant inverse correlation ($r=-0.74$; $p<0.05$; $n=9$).

Suspended matter was correlated directly with particulate organic carbon ($r=0.73$; $p<0.01$; $n=13$) and total organic carbon ($r=0.59$; $p<0.05$; $n=13$).

The average of Kjeldahl nitrogen and ammonium (Table 3) increased 42% and 53% respectively at SMT regarding GOR. Both variables showed significant differences between sites ($p<0.001$), registering the highest values at MOR. The average of Kjeldahl nitrogen at SMT was approximately half of that at MOR. However, in December, Kjeldahl nitrogen and ammonium at SMT were similar to those at MOR related with smaller relative discharge at SMT with regard to MOR. Ammonium represented on the average from 85 to 97% of the dissolved inorganic nitrogen, the highest percentages being at SMT and MOR. Nitrates and nitrites (Table 3) showed significant differences among the sites ($p<0.001$; $p<0.01$, respectively) registering the highest values at GOR. Nitrates were correlated positively with dissolved oxygen ($r=0.82$; $p<0.001$; $n=15$), the highest levels of nitrates and nitrites being in coincidence with an important increment of dissolved oxygen at GOR, in December. At SMT the concentration of nitrates was six times lower than at GOR.

Soluble reactive phosphorus represents 41.5 to 67.1% of total phosphorus. The highest values in soluble reactive phosphorus and their percentages with regard to total phosphorus were registered in October and February, reaching 100% at GOR. The concentrations of soluble re-

Table 3. Physicochemical variables measured.

	GOR					MOR					SMT				
	Jun 96	Aug 96	Oct 96	Dec 96	Feb 97	Jun 96	Aug 96	Oct 96	Dec 96	Feb 97	Jun 96	Aug 96	Oct 96	Dec 96	Feb 97
DO (mg l^{-1})	1,2	0,4	0,6	7,8	4,4	0,6	0,4	0,3	0,1	0,4	0,0	0,2	0,2	0,0	0,4
Temp. (°C)	13	13	21	29	22	16	17	25	30	23	14	15	23	30	23
pH	8,1	8,0	7,8	8,4	8,0	7,8	8,4	7,5	7,6	7,5	7,7	8,1	8,0	7,5	7,9
Cond. ($\mu S\ cm^{-1}$)	1.270	839	-	1.217	1.677	3.115	2.295	-	2.143	3.090	2.125	1.295	-	1.923	1.550
Secchi (m)	0,69	0,15	0,56	0,40	0,48	-	-	-	-	-	0,54	0,11	0,25	0,12	0,40
SM (mg l^{-1})	-	74	17	19	31	199	-	110	54	82	50	156	64	64	44
NKj (mg l^{-1})	22,7	15,40	10,92	10,08	15,96	51,80	55,72	44,52	25,76	49,00	22,68	25,48	21,28	24,64	22,68
N-NH_4^+ (mg l^{-1})	10,3	8,28	6,71	8,25	10,31	13,24	13,50	16,76	17,11	34,31	10,98	9,45	13,67	22,46	20,06
N-NO_3^- (mg l^{-1})	1,03	1,61	0,23	3,03	0,94	0,08	0,12	0,00	0,14	0,04	0,24	0,32	0,09	0,20	0,02
N-NO_2^- (mg l^{-1})	0,73	0,38	0,48	0,59	0,00	0,22	0,04	0,00	0,03	0,02	0,04	1,16	0,00	0,03	0,01
DIN (mg l^{-1})	12,09	10,27	7,41	11,87	11,25	13,54	13,66	16,76	17,28	34,38	11,26	10,93	13,76	22,69	20,10
TP (mg l^{-1})	2,68	2,05	2,12	2,50	2,30	3,73	3,53	4,16	2,61	2,83	3,45	1,94	2,31	2,46	2,59
SRP (mg l^{-1})	1,25	1,12	2,02	0,85	2,24	1,15	0,77	2,63	0,73	1,80	1,65	0,77	2,16	0,73	2,19
POC (mg l^{-1})	1,6	4,6	0,7	2,5	2,5	13,9	17,1	19,8	9,6	20,2	5,3	22,3	10,3	6,0	8,7
TOC (mg l^{-1})	29,3	33,7	10,5	15,4	19,5	120,6	323,0	226,1	62,3	138,9	74,7	80,8	35,6	72,8	54,9
Ca^{2+} (mg l^{-1})	27,1	29,1	24,2	26,8	29,4	80,4	70,9	70,9	51,0	65,7	54,9	44,5	44,7	49,0	41,8
Mg^{2+} (mg l^{-1})	16,3	13,5	12,9	15,4	13,6	34,4	29,5	42,3	19,3	25,5	23,1	16,5	17,7	23,7	15,8
Na^+ (mg l^{-1})	222,8	145,6	154,9	192,7	178,2	699,0	424,2	406,9	344,0	355,8	294,0	208,6	226,3	277,1	230,4
K^+ (mg l^{-1})	14,6	14,8	12,7	15,9	14,1	217,7	116,1	116,6	29,2	69,5	30,0	33,4	23,1	53,7	19,7
HCO_3^- (mg l^{-1})	721,8	549,6	514,2	610,9	632,1	849,1	757,1	700,5	587,3	823,2	718,2	534,2	566,1	577,9	665,1
SO_4^{2-} (mg l^{-1})	24,2	22,9	41,0	13,8	37,4	102,5	139,8	177,8	68,2	136,8	90,0	66,5	94,2	77,0	74,1
Cl^- (mg l^{-1})	86,4	56,8	49,7	67,5	112,4	408,3	363,9	431,9	301,8	444,9	211,2	177,5	179,9	210,6	176,3

active phosphorus and total phosphorus did not register an important increase between GOR and SMT.

The levels of particulate organic carbon and total organic carbon showed significant differences among sites ($p<0.01$ and $p<0.001$ respectively), presenting the highest values in particulate organic carbon at SMT and MOR and the highest levels in total organic carbon at MOR. These variables increased 3 and 4 times at SMT with regard to GOR, indicating an important matter discharge from the Morón stream.

Bicarbonate and sodium were the principal ions in the river. The bicarbonates in the Reconquista River did not increase significantly downstream from the confluence with the Morón stream. On the other hand, calcium, magnesium, sodium, potassium, sulphate and chloride registered significant increases from 23% to 174% at SMT regarding GOR. In December, the levels of these variables at SMT were quite similar and even higher than at MOR, in coincidence with the lower diluting effect of the Reconquista River (Table 2). In February, when the diluting effect of the Reconquista River was higher (Table 2), the levels of all variables measured at SMT were lower than at MOR.

According to ICA index, all samplings at SMT and MOR, and at GOR in October, presented sewer level contamination, and GOR in the rest of dates presented high contamination.

According to daily load balance of the main variables that reflect organic contamination (Table 4), the highest values were found at SMT, except for the total organic carbon.

In the PCA, 72.9% of the total variance was explained using two components. Component I accounted for 61.6% of the total variance and had the following variables related to its positive extreme: Kjeldahl nitrogen, total phosphorus, total organic carbon, particulate organic carbon, calcium, magnesiun, sodium, potassium, bicarbonate, sulphate, and chloride (Table 5). This component showed a spatial gradient of mineral and organic pollution along the stream. Component II accounted for 11.3% of the total variance and had dissolved oxygen related to its positive extreme. Ordination of sites in the I-II plane (Fig. 2) showed spatial location of sites along axis I. GOR samplings were located in the left extreme. In the other extreme, the samplings of MOR were located, except December. In the center were located all the samplings of SMT, and December samplings of MOR. December samplings of GOR was separated by the second axis, lying within the positive region.

The metal concentrations, except cadmium, were higher on the average than thresholds proposed for aquatic life protection by Argentine Law of Dangerous Residues (N° 24,051) (Table 6). According to these limits, the more hazardous metals were: lead, copper, zinc and chromium. Lead, zinc and manganese levels increased to 5 times and chromium to 35 times at SMT regarding GOR. In August, the levels of heavy metals at GOR and SMT were higher than at MOR. In October, the concentration of heavy metals diminished with regard to the other samplings, the concentrations of almost all the heavy metals being lower than the levels for the protection of the aquatic life.

Table 4. Load balance of the main variables of organic contamination.

	NKj (kg day^{-1})	N-NH_4^+ (kg day^{-1})	TP (kg day^{-1})	SRP (kg day^{-1})	TOC (kg day^{-1})	POC (kg day^{-1})
GOR	1.318	791	211	139	1.743	201
MOR	2.359	987	175	74	9.057	838
SMT	3.116	2.007	360	209	8.211	1.363

Table 5. Variance explained and component loadings for PCA axes I-II.

Component	Eigenvalue	% Total Variance	Cumulative Eigenvalue	% Cumulative Variance
I	9,2	61,6	9,2	61,6
II	1,7	11,3	10,9	72,9

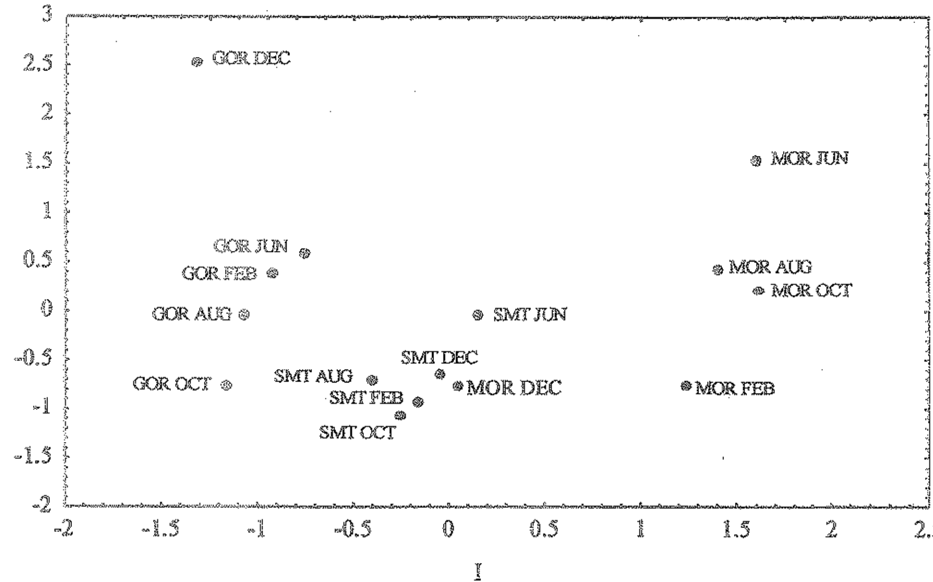

Fig. 2. Location of the samples in the plane defined by components I and II.

Table 6. Heavy metal concentrations and their respective levels proposed for protection of aquatic life by the Argentine Law of Dangerous Residues (N°24,051).

	GOR	MOR	SMT	Levels for protection of aquatic life
Mn (µg l⁻¹)	(64-123)	(7-269)	(7-299)	100
Fe (µg l⁻¹)	(362-2,570)	(16-2,275)	(18-3,083)	-
Cu (µg l⁻¹)	(28-304)	(2-142)	(1-98)	2
Zn (µg l⁻¹)	(46-147)	(28-472)	(11-188)	30
Cr (µg l⁻¹)	(2-8)	(0.3-850)	(0.1-561)	2
Cd (µg l⁻¹)	(0.04-1)	(0.01-5)	(0.004-1)	0,2
Pb (µg l⁻¹)	(13-114)	(0.3-273)	(0.2-130)	1

DISCUSSION

Due to lack of flow data for the sampling dates in the sampling sites, the estimation of relative discharge of the Reconquista River at SMT with regard to that of the Morón stream, represented a good indicator of a relative flow variation. The average of the relative discharge estimations here reported was roughly coincident with the Reconquista/Morón flow ratio attained from the flow data estimated by the Thames Water Consultancy Service (1979).

The conductivity at MOR was higher than at other sampling sites on all dates. When the relative discharge at SMT with regard to MOR was highest, the conductivity at SMT and GOR was similar. On the other hand, when the relative discharge was lowest, the conductivity at SMT was similar to that at MOR. The same effect was observed for calcium, magnesium, sodium, potassium and sulphate concentrations. The increase of river flow would contribute to attenuate the effect of the Morón stream at least regarding to these variables.

Like in other streams of Buenos Aires (López *et al.*, 1998; Mercado, 1999), bicarbonates and sodium were the principal ions in this river.

The direct correlation between the suspended matter and particulate and total organic carbon would indicate that this matter contains an important organic component, contrary to the Matanza-Riachuelo River (López *et al.*, 1998) supporting similarly high pollution loads.

The level of contamination at SMT was higher than at GOR. At SMT, the high discharge of total organic carbon and the low levels of dissolved oxygen, arriving at levels of almost anoxia, indicated important bacterial consumption. Present results suggest that the high organic matter load determines the oxygen depletion and that nitrification is limited by oxygen availability. These variables were very strongly influenced by the discharge of the Morón stream. Nevertheless, this stream did not produce an increase in the phosphorous concentrations, either soluble or total, at SMT.

According to the index of water quality, SMT and MOR always showed a contamination level similar to a sewer effluent, while at GOR the conditions were slightly better, indicating high contamination. This index confers to ammonium the highest relative weight.

The loads obtained for the different variables indicated that the important organic contamination of this river was due mainly to the Morón stream. According to load balance, we found that SMT loads corresponded approximately to the addition MOR and GOR.

According to PCA, the sites were ordered following a growing gradient of organic and mineral contamination in GOR, SMT and MOR. In December, MOR presented intermediate levels of contamination being located near the samplings of SMT. Besides, the smallest diluter effect of the Reconquista River in this month produced similar characteristics in SMT and MOR.

The levels of all metals analized were, on the average, higher than levels of protection of the aquatic life, and the most dangerous were lead, copper, zinc and chromium. The increment of lead, zinc, manganese and chromium at SMT responded to the industrial activity of the area, where the predominant are textile, chemical, tanneries and metallurgical. In August, the levels of heavy metals at GOR and SMT were higher than at MOR, indicating important contributions of toxic pollutants to the river besides the Morón stream. The heavy metal concentration was not related to the relative discharge at SMT and could be attributed to an irregular and intermittent spillage of toxic effluents.

CONCLUSIONS

According to the variables involved in the organic contamination, MOR was the site with the most human impact, followed by SMT and GOR.

The gradient of organic and mineral contamination of the Reconquista River had a spatial component and another one related to the flow. The first component was given mainly by the discharge of the Morón stream. The second component was related to the dilution level of its waters.

Considering the levels of heavy metals in water, the tendencies were quite irregular having on occasions a higher toxic load at SMT and GOR than at MOR. The toxic contamination by heavy metals depended mainly on the intermittent and irregular discharge of the effluents. In this river, the level of this kind of contamination would not depend on the flow.

In order to perform river restoration plans and to evaluate water quality it is indispensable to keep in mind the value discharge and the precipitation régime. Also, although the Morón stream is the main responsible for the deterioration of the Reconquista River, other pollutant discharges exist in punctual and diffuse form that worsen this situation.

ACKNOWLEDGEMENTS

We acknowledge Prefectura Naval Argentina for supporting the field trips during samplings and Lic. Roberto Serafini for collaboration in data statistical analysis.

BIBLIOGRAPHY

AGOSBA. 1991. *Plan de Control de la Contaminación Industrial en la Cuenca del Río Reconquista*. Ministerio de Obras y Servicios Públicos, La Plata, Provincia de Buenos Aires, Argentina.

APHA – AWWA – WPCF. 1992. *Métodos normalizados para el análisis de aguas potables y residuales*. Ed. Díaz de Santos. S.A, Madrid.

Arreghini, S., L. de Cabo, A.F. de Iorio, A. Rendina, M. Bargiela, G. Godoy di Pace, A. Corujeira, R. Vella, y C. Bonetto. 1997. Evaluación de la calidad de aguas del Río Reconquista a través de índices. *Congreso Internacional sobre Aguas, Facultad de Derecho, UBA.*

Berón, L. 1984. *Evaluación de la Calidad de las Aguas de los ríos de La Plata y Matanza-Riachuelo, mediante la utilización de índices de calidad de agua*. Secretaría de Vivienda y Ordenamiento Ambiental, Ministerio de Salud y Acción Social, Buenos Aires, Argentina.

Castañé, P.M., M.L. Topalián, M.G. Rovedatti & A. Salibián. 1998. Impact of human activities on the water quality of the Reconquista River (Buenos Aires, Argentina). *Verh. Internat. Verein. Limnol.* 26: 1206-1208.

Daniel, W.W. 1978. *Applied Nonparametric Statistics*. Houghton Mifflin Company, Boston, 513 pp.

García, M.E.; S.O. Demichelis, F.R. de la Torre, & L. Ferrari. 1998. Freshwater toxicity to *Cnesterodon sp.*: bioassays with water from the Reconquista River. *Verh. Internat. Verein. Limnol.* 26: 1216-1218.

Golterman, H., R. Clymo, & M. Ohndtad. 1978. *Methods for the physical and chemical examination of freshwaters*. Blackwell Sci. Publ., Oxford, 166 pp.

Jolánkai, G. 1997. Basic river water quality models. Computer aided learning (CAL) programme on water quality modelling. *IHP-V, Technical Documents in Hydrology* N° 13, UNESCO, Paris, 50 pp.

Kuczynski, D. 1994. Estudio Ambiental de un curso de agua urbano altamente deteriorado por acción antropógena (arroyo Morón, provincia de Buenos Aires, Argentina). *Revista de Ecología Médica y Salud Ambiental*. 1(4): 1-14.

López, L.C., A. Magdaleno, L. de Cabo, M.F. Noriega, M. Bassi, S. Arreghini, G. Bassols, M. Wagner y J. Moretton. 1998. Estudios de mutagenicidad, inhibición del crecimiento algal y contaminación química en aguas superficiales de un río urbano de Buenos Aires, Argentina. *Rev. Int. Contam. Ambient.* 14 (1): 27-37.

Mackereth, F., J. Heron & J. Talling. 1978. Water Analysis: some revised methods for limnologists. *Freshwater Biological Assoc. Scientific Public.* N°36, 120 pp.

Mercado, L.M. 1999. Consideraciones acerca de la calidad de las aguas de seis sistemas lóticos de la Provincia de Buenos Aires (Argentina). APRONA, Año XIII, N°38: 10-16.

Olson, D., E. Dinerstein, P. Canevari, I. Davidson, G. Castro, V. Morisset, R. Abell & E. Toledo. 1998. *Freshwater biodiversity of Latin America and the Caribbean: A conservation assessment*. Biodiversity Support Program, Washington D.C, 70 pp.

Pescuma, A. & M.E. Guaresti. 1992. *Proyecto de Saneamiento Ambiental y Control de Inundaciones de la Cuenca del Río Reconquista*. Informe final. Buenos Aires, Argentina.

Pla, L.E. 1986. *Multivariate Analysis: Principal Components Methods*. Organization of American States, Washington D.C, 94 pp. (in Spanish).

Saltiel, G. 1997a. Situación ambiental en la cuenca hídrica del Río Reconquista. Problemas y soluciones. Primera parte. *Ingeniería Sanitaria y Ambiental* 31: 45-55.

- 1997b. Situación ambiental en la cuenca hídrica del Río Reconquista. Tercera parte: el proyecto de saneamiento. *Ingeniería Sanitaria y Ambiental* 34: 46-54.

Strickland, J. & T. Parsons. 1968. A practical Handbook for seawater analysis. Bulletin 167. *J. Fish. Res. Bd. Can.*, Ottawa, Canadá.

Thames Water Consultancy Service. 1979. *Investigación sobre la contaminación del Río Reconquista*. Informe. Buenos Aires, Argentina.

Recibido: 28-IV-2000
Aceptado: 15-IX-2000