*Int. J. Environ. Res., 9(3):1037-1046, Summer 2015*
*ISSN: 1735-6865*

# Estimating the Self-depuration Capacity of a Reach of the Luján River

**Piccinini, M.[1], Sánchez Caro, A.[2] ,Gultemiriam, M. L.[3,4] and Giorgi, A.[2,4*]**

[1]Municipalidad de Luján. Dirección de Medio Ambiente, Bromatología y Sanidad Animal. José María Pérez y Champagnat, (6700) Luján, Argentina

[2]Instituto de Ecología y Desarrollo Sustentable (INEDES) and Departamento de Ciencias Básicas (GEA-PEP), Universidad Nacional de Luján, CC221, Buenos Aires, (6700) Luján, Argentina

[3] Facultad de Ciencias Naturales e Instituto Miguel Lillo, UNT, Miguel Lillo 205, 4000 San Miguel de Tucumán, Tucumán, Argentina

[4] CONICET- Av. Rivadavia 1917 (C1033AAJ) C.A.B.A. Argentina

Received 8 Oct. 2014; Revised 27 Dec. 2014; Accepted 1 Jan. 2015

**ABSTRACT:** A 3-km reach of the Luján River was studied by establishing 6 sampling stations, which were from 300 to 500 m apart. The first station was the control reading for river nutrients and particulate material. The second station measured the continuous effluent from a wastewater treatment plant flow of the city of Luján and was, therefore, considered a continuous addition point of nutrients. The other 4 stations were used to evaluate whether the river captured phosphorus as phosphate, nitrogen as ammonium, nitrite or nitrates, and the suspended particulate material, both organic and inorganic. These data were used to calculate material uptake (U), uptake velocity ($V_f$), and net distance $S_{net}$ under two different hydrological situations, during low and high flow, during the same season of the same year. Results indicate that phosphate ions as well as organic matter are retained for less than 2 km in both high and low flow situations. In the case of ammonium, the results appear similar to those of phosphate ions but it may be transformed into nitrates and transported in the latter form for greater distances. It is concluded that this river, in the reach under study, has a variable retention speed according to its flow but the retention capacity is no less than 900 m and as much as 2000 m. Therefore, a 2 km distance must be considered as the minimum distance before another effluent of nutrients or organic matter is added.

**Key words:** Material uptake, Nutrients, Particulate matter, Luján River

## INTRODUCTION

Margalef (1983) describes a river as “an ecosystem under tension, which is overfed and exporting part of its materials, maintaining a relatively accelerated cycle” and adds that, in this model, “the final sections will be the most eutrophic”. Smith and Smith (2002) describe the functions of lotic systems and underscores the importance of the organic matter that supports these systems. He adds that it is fundamentally allochthonous and is represented by coarse organic matter (leaves and wood remnants), fine organic matter (leaf fragments, invertebrate feces and precipitation of dissolved organic matter), and dissolved organic matter (from rainwater washing leaves, sub superficial flow and the release of effluents). On the other hand, autochthonous material comes from algae and aquatic plants. This means that rivers often have organic matter from allochthonous as well as autochthonous material, but it has to be taken into account that those that receive wastewater effluents are mainly influenced by them unless the effluent has little flow or charge.

The majority of the communities are found in particular sites of the river in relation to submerged vegetation, meanders and other features that reduce flow speed. Both planktonic and benthonic communities are found in sites where changes in water flow occur. Regarding nutrient cycling, it could be represented by a spiral that revolves downstream around a longitudinal vector. A cycle would comprise the distance covered by a nutrient, starting with its release from the dissolved organic matter and its incorporation by an organism, until it is released again to the environment. This theoretical pathway should be followed by organic matter as well as nutrients

---

*Corresponding author E-mail:adonis@coopenetlujan.com.ar incorporated into the river (Newbold *et al.*, 1981) and we can say that it would also be the pathway of biodegradable effluents (Heidenwag *et al.*, 2001).

According to Branco (1984), depuration is the action of the river itself and therefore it can be designated as self-depuration. This author establishes a distinction between toxic and non-toxic contaminants concluding that, in the latter, the process that returns conditions to the original settings would be more appropriately designated as "stabilization".

Heindenwag *et al.* (2001) refer to self-depuration as the assimilation of organic matter and nutrients dissolved in the water by bacteria, plants and animals, and it would also include processes of dilution and mixture of organic matter and nutrients. They also claim that it is a process that allows to preserve ecological equilibrium and therefore it is a fundamental parameter that describes ecosystem function. Smith and Smith (2002) maintains that streams can self-depurate in a natural way, by decomposing organic matter through bacterial activity, and that the time required will depend on the degree of pollution and stream characteristics. Palmeri (2002) states that the more diverse the environment, the more biodiversity in the consumer community, which guarantees the filtering and purifying action of the waters. Doménech (2000) mentions sedimentation, adsorption and aeration as self-depuration processes. Sedimentation is inversely proportional to the speed of the water flow and directly proportional to particle size. Aeration provides the oxygen needed for the biological oxidation of organic matter, and is the major route for its disposal. With respect to nutrients, according to Margalef (1983) phosphorus is the most limiting factor, nitrogen is the second most limiting factor. Periphyton or biofilm is a community that has a particularly important activity in the self-depuration process (Heindenwag *et al.* 2001). This has been found to be true in the case of phosphorus uptake in Las Flores stream in the Luján River basin in Buenos Aires Province, Argentina (Feijoó *et al.*, 2011). Organic matter with an intact molecular structure will buffer ecosystem changes. According to its composition, organic matter will be easier or more difficult to capture and digest and its decomposition will be gradual and selective. On the other hand, particulate matter, besides transforming into dissolved matter, concentrates the latter into its surface and favors its decomposition by microorganisms. Regarding humic material, its presence could constitute a buffer, since it is a stable product which has not achieved its maximum oxidation and it tends to associate with clay, depending on water pH. According to Rheinheimer (1987), suspended organic matter and debris, play an important role as substrates to numerous microorganisms as bacteria because they concentrate nutrients on their surfaces and covered by a polymeric structure that, besides providing adhesion, protects them from harmful chemicals. In turn, debris captures toxic and inhibitory compounds, benefitting bacterial growth. Many bacteria stay inactive when nutrients are scarce but they change their development according nutrient conditions.

Uptake distance has been defined as the mean distance required by the subsystem to achieve the net removal of material equal to advective flow. The values can be positive (uptake > release) or negative (uptake < release), in the latter case, it means that the subsystem is behaving as a source, releasing the material of interest. The present work attempted to address both aspects, retention distance and release if nutrients taking self-depuration as the main issue. Our objective was to find out the purification capacity of a river that has been impacted by human activities upstream from the segment under study. To this end we proposed to estimate the distance of uptake and/or processing of organic matter and inorganic nutrients released by a wastewater treatment plant.

The study area is a 3-km reach located in the middle segment of the Luján River, Buenos Aires, Argentina. The area of the Luján River basin is described by Andrade (1986) and Sala *et al.* (1972) as temperate and sub humid. It has a summer mean temperature of 25 ºC and a winter mean of 19.5 ºC and presents moderate thermal amplitudes of approximately 10 ºC due to its relative high humidity. The mean annual precipitation is 950 mm with a maximum of 1300 and 1400 mm in autumn and spring, respectively, and a minimum of 600 mm in winter. The Luján River starts in Suipacha – Province of Buenos Aires – at 59º 37' W and 34º 43' 54'' S., at the junction of the Durazno and Los Leones streams. From its source to its mouth the river crosses the counties of Mercedes, Luján, Pilar, Exaltación de la Cruz, Campana, Escobar, Tigre and San Fernando. Its main direction is SW to NE up to the vicinity of the junction with National Route 9, where it makes a sharp bend to the SE and becomes parallel to the Paraná de Las Palmas, merging with the Delta near its mouth at the Río de la Plata. The basin is roughly rectangular, with an area of 3,295 km$^2$ and a total length of 450 km, of which 128 km are the main course of the Luján River. Its average flow is 5.37 m$^3$/s and an average slope of 0.44 m/km. Its upper course extends from the headwaters to the town of Jáuregui, it has an approximate length of 40 km and an average gradient of 0.40 m/km. The middle course runs approximately from the town of Jáuregui to the junction with National Highway No. 8 and it has a length of almost 30 km and an average slope of 0.83 m/km. This section presents hills and has a large number of affluents. The lower course extends from intersection mentioned above to the river mouth and it has an approximate length of 60 km and an average slope ranging from 0.16 m/km to 0.05 m/km – this gentle slope determines an uneven drainage that ends in extensive marshes–. The flow regime of the river is regular; with marked high volume in autumn and spring and reduced flow mainly in winter. Therefore, the Luján River drains a rural area and runs through three cities, each one with less than 100,000 inhabitants including the city of Luján after which the section studied was chosen.

## MATERIALS & METHODS

The river reach chosen for this study includes the site where a wastewater treatment plant releases the treated water from the city of Luján. The first sampling site is located upstream of effluent release and it gives the basal readings of the variables. The second is the site of release of the effluents of the wastewater treatment plant and there are four more sampling sites downstream from it to evaluate if self-depuration is occurring. The distances among the six sites are the following: 638m (S1-S2), 346m (S2-S3), 601m (S3-S4), 611m (S4-S5) and 597m (S5-S6). The reach was selected in order to avoid tributaries or effluent streams that may result in incoming or outgoing materials. Table 1 shows the details of the variables analyzed, methodology employed and mode of sampling. Samples were taken in 10-liter plastic containers. Those samples used in nutrient determinations were kept in containers washed with hydrochloric acid and rinsed with double-distilled water. Samples used to determine chlorophyll a were transported in the dark, in an ice bath and those for nutrient analysis, were kept at -20$^{o}$C, after reaching the laboratory, until they were processed.

To study the 2.8-km reach, river flow was calculated at its beginning and end and the volume of effluent released from the wastewater treatment plant was calculated as well. This was done based on the speed of the river flow and its cross section (Gordon *et al*., 1996). The cross sections of the river were estimated measuring its width and depth every 0.5 m. With these data, appropriately scaled models were constructed with graphing paper, which was weighed; the results were transformed to real size areas. The same methodology was used to calculate the effluent section. The river flow speed was obtained with a flowmeter from General Oceanics. To determine the uptake of each nutrient in this river reach, we proceeded as follows: a) Measurements were done at each of the selected sites, b) The normalized concentration (NC) of the nutrient was obtained.

This was done by subtracting the measured concentration, Cx, from the basal reading, Cb, – in this case at site 1, taken as the initial reading– and dividing this difference by the chloride concentration, “C, (as a correction of the dilution effect); that is: NC = (Cx-Cb)/ ”C chloride. c) The natural log of the NC of the nutrient as a function of distance was plotted. d) The slope from the regression line was obtained from the graph. This slope represents the uptake rate of the reach and its inverse, $S_w$, is the nutrient uptake distance, that is, the distance a nutrient molecule travels in water. It is considered that $S_w$ is the length of the longest spiral since the distance would be shortened when an organism captures it. Uptake distance calculations were performed as linear regressions to estimate these values (Newold *et al.*, 1981; Stream Solute Workshop, 1990). Uptake (U) is an estimate of nutrient retention capacity at basal concentration and uptake velocity (Vf) is an estimate of the speed at which an element is removed from the water column by the benthos compartment. $U = C\ Q / S_w\ W$, where C is the nutrient concentration at ambient levels at station 1, $S_w$ is the nutrient uptake distance, Q is the stream discharge, and W is the average stream width in the reach (Stream Solute Workshop, 1990). $Vf\ (m/s) = V\ D / S_w$, where V is the mean current velocity, D mean reach depth, and $S_w$ is the nutrient uptake distance. According to Haggard *et al.*(2005), $S_w$ is a component of the spiral length and can be established based on a discrete nutrient discharge, while $S_{net}$ is the net distance and can be established when nutrients are continuously added, as is the case in effluents from a wastewater treatment plant. According to these authors $S_w$ y $S_{net}$ are calculated in the same manner. $U_{net}$ and $Vf_{net}$ could be established in. a similar way.

## RESULTS & DISCUSSION

Samples were taken at high and low flow, 890 L/s and 115 L/s, respectively. Calculations of uptake

**Table 1. Variables analyzed, methodology and units employed.**

| Variables | Methodology | Units |
|---|---|---|
| Nutrients: phosphates, ammonium, nitrites, nitrates. | According APHA (2005), using a Shimadzu UV-visible light spectrophotometer | mg ion/l |
| Chlorides | Silver nitrate titration method, according to APHA (2005) | mg/l |
| Suspended particulate matter and organic matter | According to Wetzel – Likens (1995) | mg/l |

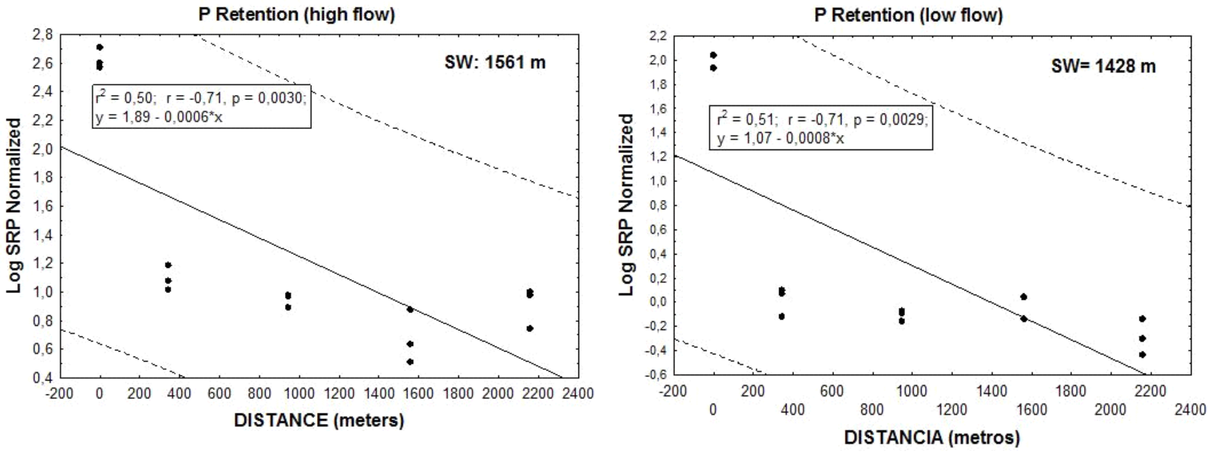

**Fig. 1. Normalized phosphate data of the Luján River as a function of distance en high and low flow situation.**

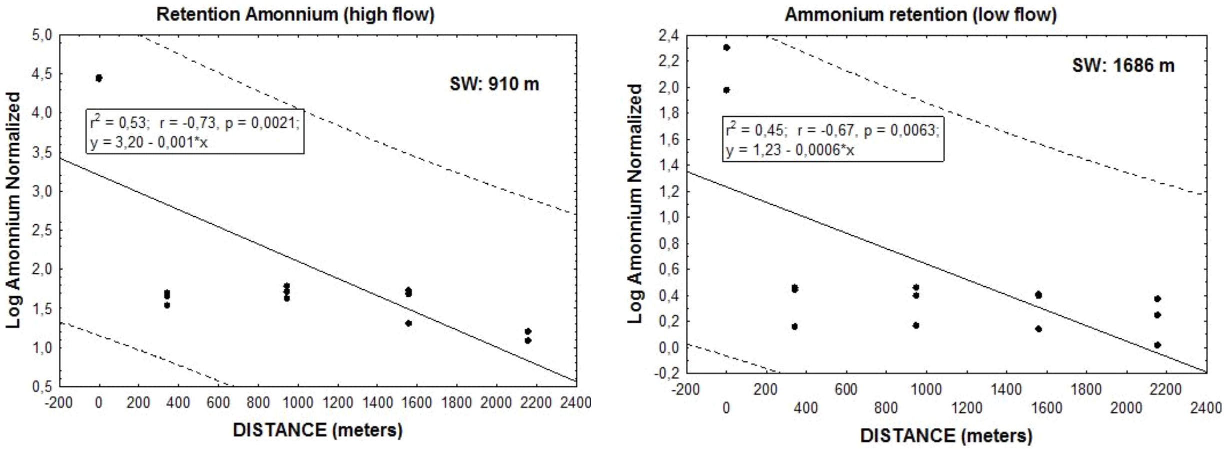

**Fig. 2. Normalized ammonium data of the Luján River as a function of distance en high and low flow situation.**

capacity for particulate matter and soluble matter often produce different distances for the same material, depending on the stream. The phosphate level of the river in this study is restored at a distance of 1,561 m from the treatment plant in high flow conditions and 1,428 m during low flow (Fig. 1); while the distance for ammonium ranged between 1,686 m with high flow and 910 m during low flow (Fig. 2).

However, nitrates need a distance three times longer for uptake (4,875 m) during low flow and the distance could not be determined for high flow (Fig. 3). As to the distance needed to retain nitrites, it was 1,736 m during high flow, and it could not be established at low flow (Fig. 4).Organic and inorganic particulate matter retention distances were similar to ammonium and they were 1,743 and 1,746, respectively (Fig. 5 and Fig. 6).In order to compare more adequately the retention capacity in situations of high and low flow, U and Vf were calculated (Table 2).

From baseline values and transported load presented in Table 3, it can be seen that the proportion of inorganic material carried is around 25% of the total particulate matter while 75% corresponds to particulate organic matter.

This study attempted to determine whether the Lujan River has the uptake and processing capacity of substances discharged by the effluent of a wastewater treatment plant. Through the methodology used it has been demonstrated not only that the river has self-purification capacity but also the uptake distances of different ions and materials. These have been estimated using the methodology originally described by Newbold *et al.*, 1981, discussed in Stream Solute Workshop, 1990 and applied by Martí and Sabater (1996) and Acuña (2002), who consider that these distances would be indicators of self-purification capacity of rivers. As summarized in Tables 2 and 3, in general, results ndicate that when considering the

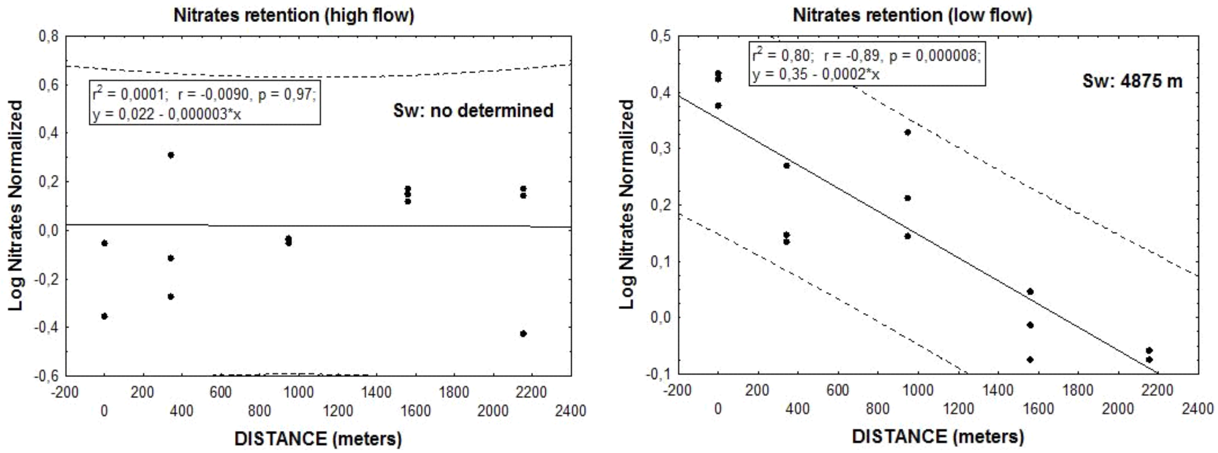

**Fig. 3. Normalized nitrate data of the Luján River as a function of distance en high and low flow situation.**

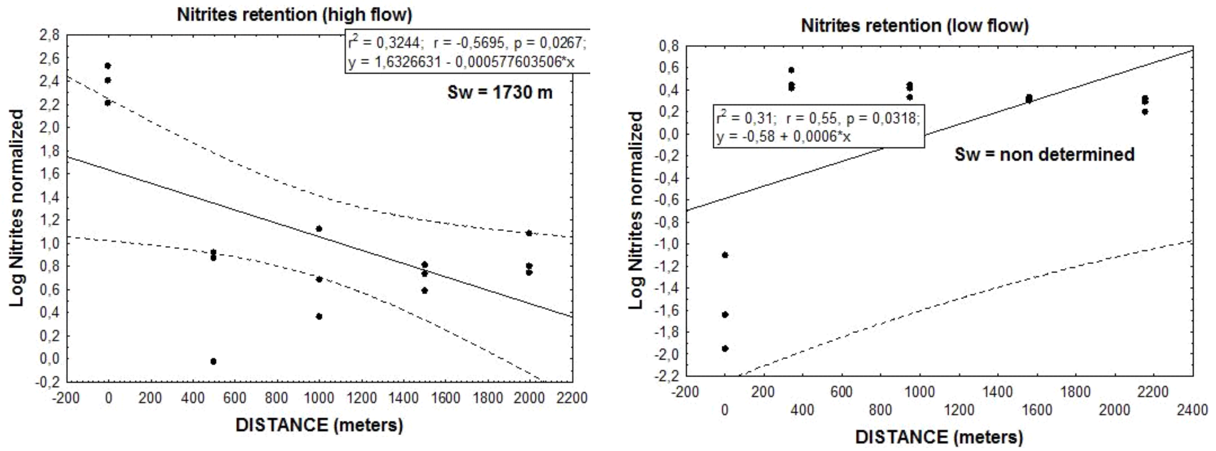

**Fig. 4. Normalized nitrite data of the Luján River as a function of distance en high and low flow situation.**

phosphate, ammonium, and nitrate ions, the higher the load, the longer the nutrient uptake distance ($S_w$). This generalization cannot be established with respect to the basal concentration, the flow, the uptake capacity (U), or the uptake velocity (Vf). It was also noted that at similar load values corresponded similar uptake distances for phosphate and ammonium, and these were shorter than those for nitrate retention. These results are consistent with those reported by Martí *et al*., 2004 in streams with continuous discharges from a wastewater treatment plant in which only primary and secondary treatment of wastewater are done.

It should be taken into account that, in the case of nitrogen compounds, the different chemical species may interconvert depending on the level of oxygenation of the water, the presence of nitrifying and denitrifying bacteria and organisms like cyanobacteria that have the ability to fix atmospheric nitrogen (Darley, 1991). This may be one of the reasons that explain why the uptake distance could not be established for nitrites. In addition, this indicates that the estimated uptake distance of ammonium or nitrates can actually reflect when an ion is converted into another. This does not mean a real reduction of nitrogen in water but it indicates that it is part of the spiral or cycling of these compounds (Martí *et al*., 2004).

With respect to the particle matter in suspension, uptake distance of both materials (organic and inorganic) was longer when the load was smaller, and corresponded to the low flow situation. With high flow, the inorganic material had a shorter retention distance than the organic material; in this case it could be due to the energy of the stream and its relationship with particle settling. It was also observed in both flow conditions that, although the load of the particulate material was much higher than those of the phosphate and ammonium, the uptake distances were similar to the retention of these ions; this was even more

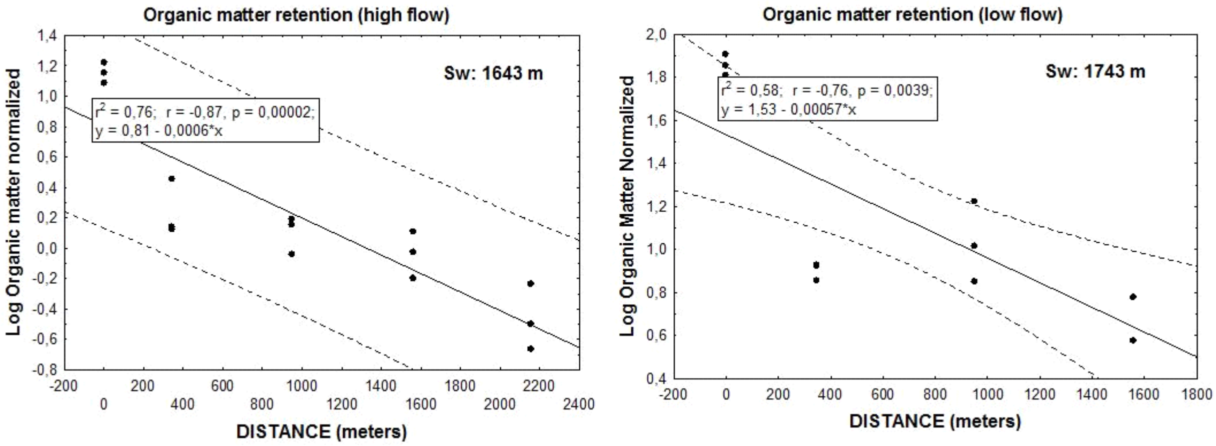

**Fig. 5. Normalized of suspended organic matter data of the Luján River as a function of distance en high and low flow situation.**

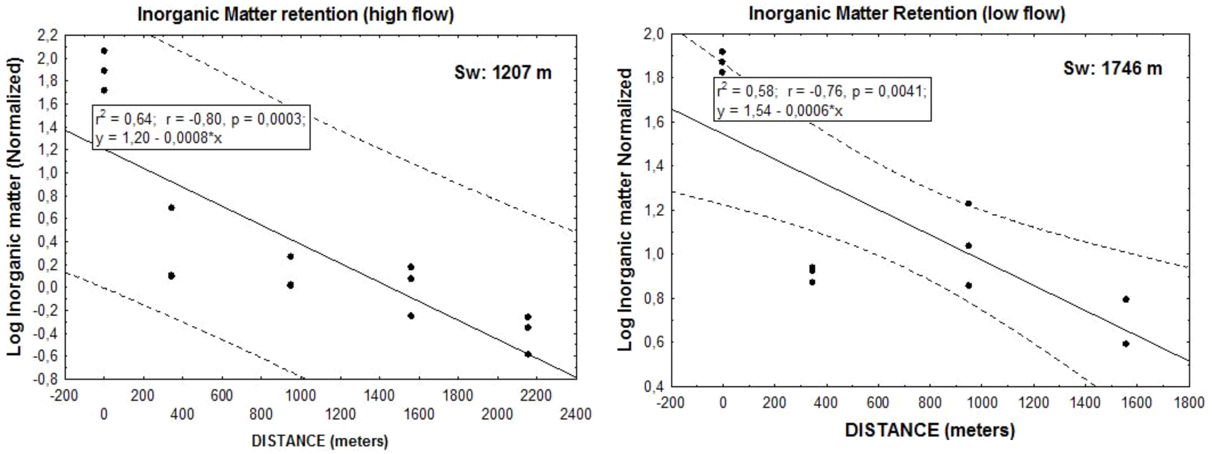

**Fig. 6. Normalized of suspended inorganic matter data of the Luján River as a function of distance en high and low flow situation.**

noticeable when comparing uptake distances of particulate material and ammonium in the low flow situation. For phosphates and ammonia, the highest uptake capacity appeared in the situation of high load of both, which coincided with the longest uptake distances. When the load of both was similar (in low flow), uptake capacities were similar.

In the case of nitrates, a decrease in the retention capacity was observed as the load increased, and this corresponded to an increase of the retention distance. In general, if we except nitrates, the mass transfer coefficient is higher in the high flow situation; and for phosphates and particulate matter it coincides with greater holding capacity. These results may be explained by expressing uptake as U = Cb Vf. Thus, the retention capacity could be explained by the basal concentration, the mass transfer coefficient, or both parameters. As flow increases so does the mass transfer coefficient but to a certain limit at which bottom sediments are disturbed. If the load is reduced, the uptake capacity is also reduced while the mass transfer coefficient increases.

The factors that can be taken as contributing to the retention of nutrients in a river with the characteristics of the Luján River are hydrochemical (hydrolysis, oxidation, degradation, mineralization, etc.) and physical (dilution, mixing, adsorption, etc.). According to Bernot and Dodds (2005), the Luján River could be placed in the category of depositional, in which retention prevails over removal. Retention of nutrients includes adsorption, biological capture, and the deposition of materials. These authors argue that nitrogen retention increases with the aid of heterotrophic organisms associated with organic matter. As the load of organic matter is large in the Luján River, the biological uptake by ciliates and

**Table 2. Comparison of retention data in the Luján River.**

| | HIGH FLOW (890 L/s) | | | LOW FLOW (115 L/s) | | |
|---|---|---|---|---|---|---|
| | Sw m | U µg/m$^2$ min | Vf Cm/min | Sw m | U µg/m$^2$ min | Vf Cm/min |
| Phosphates | 1561 | 857 | 0.191 | 1428 | 620 | 0.032 |
| Ammonium | 910 | 303 | 0.327 | 1686 | 564 | 0.027 |
| Nitrates | 344828 | 127 | 0.001 | 4875 | 270 | 0.009 |
| Inorganic matter | 1207 | 39275 | 0.246 | 1746 | 1458 | 0.026 |
| Organic matter | 1643 | 103529 | 0.181 | 1743 | 4867 | 0.026 |

**Table 3. Basal concentrations and load of the parameters observed in high and low flow in the Luján River.**

| | HIGH FLOW ( 890 L/s ) | | LOW FLOW ( 115 L/s) | |
|---|---|---|---|---|
| | Basal concentration Mg/l | Load Mg/s | Basal concentration Mg/l | Load Mg/s |
| Phosphates | 0.48 | 427.00 | 2.09 | 240.44 |
| Ammonium | 0.10 | 88.11 | 2.24 | 257.82 |
| Nitrates | 15.69 | 13967 | 3.10 | 356.81 |
| Inorganic matter | 17.00 | 15130 | 6.00 | 690.60 |
| Organic matter | 61.00 | 54290 | 20.00 | 2302 |

**Table 4. Characteristics and retention capacity of stream studied by Martí & Sabater (1996).**

| **Stream:** | La Solana | | Riera Mayor | |
|---|---|---|---|---|
| Reach | Sand-Pebbles | **Bedrock** | **Sand-Pebbles** | **Bedrock** |
| Average velocity (Cm/seg) | 11.7 | 15.9 | 16.7 | 15 |
| Average depth (Cm) | 9.4 | 4 | 13.8 | 23.3 |
| Average phosphates Sw (m) | 137 | 71 | 219 | 225 |
| Average ammonium Sw (m) | 243 | 103.5 | 111 | 193 |
| Phosphates Vf (Cm/min) | 0.48 | 0.53 | 0.63 | 0.93 |
| Ammonium Vf (Cm/min) | 0.27 | 0.36 | 1.24 | 1.08 |

flagellates that can live in sediment rich in organic matter should be considered. Data from this study also point at the consideration of export of nitrogen as nitrates. According to Bernot and Dodds (2005), excess nitrate can be explained by the un-coupling between denitrification and nitrification as the first saturates at lower levels of nitrogen loading than the second. Denitrification follows Michaelis-Menten kinetics with very low saturation values, so that, even under ideal conditions, it will be limited; in a river with an average flow of 0.1 m$^3$/s, nitrogen removal by denitrification will not exceed 4% of the total load per linear kilometer.

Furthermore, these authors argue that from inorganic and organic particulate materials, through ion exchange, some clay incorporate nitrogen as fixed ammonium. However, nitrates are generally not retained in the sediments and are easily moved by the water column. Finally, these authors claim that the channelization such as exists in the Luján River, reduces its sinuousity and increases its depth, and both factors decrease the efficiency of denitrification. This is in contrast to pristine systems; in those the shallow depth increases its connectivity the river bank subsystem. The results of this study were compared to those of Martí & Sabater (1996) in Mediterranean streams. The values of average speed, average depth and $S_w$ were taken from their published work. The mass transfer coefficient, which was not reported in their article, was calculated for phosphate and ammonium from their original data (Table 4).

Comparing the observed retention distance in the Luján River with those obtained by Martí and Sabater (1996) in La Solana and Riera Mayor courses, which have less flow volume, the last two also have shorter retentions distances. Nevertheless, in all cases, Luján and La Solana and Riera Major, nitrate retention is far higher than retention of ammonium, namely, 1.6 to 3.5 times higher in La Solana; 1.4 times in Riera Mayor, and 2.9 times in the Luján. Regarding retention

**Table 5. Comparison between residence time in the Luján River and other rivers. (Perlas: Acuña, 2002; La Solana and Riera Mayor : Martí & Sabater, 1996).**

| | **Perlas River** | | | |
|---|---|---|---|---|
| Reach | A | B | C | |
| Residence time (min km$^{-1}$) | 42 | 48 | 59 | |
| | **La Solana stream** | | **Riera Mayor stream** | |
| Reach | Sand-Pebbles | Bedrock | Sand- Pebbles | Bedrock |
| Residence time (min km$^{-1}$) | 219 | 154 | 147 | 194 |
| | **Luján River** | | | |
| Reach Luján location | Low flow | | High flow | |
| Residence time (min km$^{-1}$) | 920 | | 190 | |

**Table 6. Comparison between descriptive parameters of self-depuration of the Luján and the Columbia Hollow River (Haggard *et al.*, 2001, 2005).**

| | **LUJÁN (DECEMBER)** | | | **COLUMBIA HOLLOW (JUNE)** | | |
|---|---|---|---|---|---|---|
| **Parameter** | **$S_w$ m** | **U µg m$^{-2}$ min$^{-1}$** | **$V_f$ cm min$^{-1}$** | **$S_w$ m** | **U µg m$^{-2}$ min$^{-1}$** | **$V_f$ cm min$^{-1}$** |
| Phosphates | 1428 | 620 | 0.0320 | 13400 | 720 | 0.026 |
| Ammonium | 1686 | 564 | 0.0270 | 600 | 16200 | 0.588 |
| Nitrates | 4875 | 270 | 0.0090 | -4400 | -4080 | -0.078 |

values, those calculated for the Luján River are much higher than those recorded in La Solana and Riera Mayor. Values of phosphates were: 45.3 µgr/ m$^2$ min in La Solana, 175.5 µgr/ m$^2$ min in Riera Mayor and 620.56 µgr/ m$^2$ min in the Luján River with low flow and 857 µgr/ m$^2$ min with high flow. For ammonium, the results are: 103.2 µgr/ m$^2$ min in La Solana, 186.7 µgr/ m$^2$ min in Riera Mayor; and 563.6 µgr/ m$^2$ min in the Luján River with low flow and 303.4 µgr/ m$^2$ min with high flow. Results presented in Table 4 (Martí and Sabater, 1996) are comparable to those obtained in the Luján River at high flow situation, and well above the low flow values measured in the Luján. This may be explained by a reduced thickness of the boundary layer when the speed of the current increases and this may enhance the retention of nutrients (Navarro, 2001).

Since the Mediterranean rivers studied by Martí and Sabater, (1996) and Acuña (2002) have different size, flow, and ecological characteristics from the Luján River, residence times (time taken by chloride to move along a reach) were compared. The Solana and Riera Mayor courses had similar residence times to the Luján in the reach studied in the of high flow situation (Table 5). However, the reach of the Luján River has different residence time to the Perlas River (Acuña, 2002), a waterway that carries more water than those studied by Martí and Sabater, (1996) but with very low nutrient concentrations. Acuña (2002) estimated a very low retention capacity in three different reaches of the Perlas River; for ammonium they were: 3.93, 3.08 and 0.73 µgr/ m$^2$ min, and for phosphates: 25.00, 6.82 and 2.88 µgr/ m$^2$ min. However, the values of the mass transfer coefficient for phosphates were found to be very high and were 3.99, 2.63 and 2.12 Cm/ min. Therefore, the values of the holding capacity are lower than those obtained in the Luján River by at least two orders of magnitude in both flow situations; and values of the mass transfer coefficient are higher in one and two orders of magnitude to the Luján River with high and low flow, respectively. It can be said that in the Perlas River, with a larger flow and less load, there is a decreased retention capacity and increased mass transfer coefficient. In the Perlas River, the mass transfer coefficient is large because the current speed is high practically double of those measured in La Solana and Riera Mayor. On the other hand, the concentration of the nutrients and the retention capacity are very low.

Finally $S_w$ , U and Vf in the Luján River are compared with data obtained by Haggard *et al.*, (2005) from a more similar environment to the river Luján and where $S_w$ estimates are listed. These two bodies of water are similar in the way in which nutrients enter. The Columbia Hollow is a third order tributary of Spavinaw Creek. In the study area, the course receives effluents from the wastewater treatment plant in Decatur, west of Arkansas, and this is used by the authors to determine the parameters describing the phenomenon of self-purification. Environmental conditions and flow rates are similar, when considering the Luján River in December (low flow) and Columbia

Hollow in June (maximum flow) -early summer in both cases-; and the average flow is 115 L/s in the Luján and 162 L/s in the Columbia Hollow. Comparing these situations, it was found that: in the Luján River retention distance for phosphate is an order of magnitude smaller while holding capacity and the coefficient of mass transfer is of the same order of magnitude as those observed in the Columbia Hollow.The phosphorus retention capacity appears to be similar in both courses, and the same retention area is achieved in the Luján in a shorter distance than in the Columbia Hollow. With respect to ammonium, in the Luján River, the retention distance is one order of magnitude higher, the retention capacity of two orders of magnitude lower, and the mass transfer coefficient is lower by one order of magnitude, than the values observed in the Columbia Hollow. It can be said that the processes of retention or conversion of ammonia occur with greater intensity in the Columbia Hollow than in the Luján River. Regarding nitrates, in the Luján River there is a subtle effect of self-depuration, while in Columbia Hollow all the parameters that describe this effect show negative values indicating that nitrates are not absorbed or transformed but rather exported (Table 6).

Summarizing, most studies in which retention capacity was evaluated in lotic environments were conducted in pristine environments or environments with slight disturbances. However, in recent years there have been some studies similar to the one presented here, that is, they evaluate the retention capacity of the body of water with a continuous addition from the effluent of a wastewater treatment plant (Martí *et al.*, 2004; Haggard *et al.*, 2005). In both of those studies and the present, the retention efficiency is low, therefore the retention distances are at least one order of magnitude higher than those found in unpolluted environments and are at least a kilometer or greater. Retention distances can be interpreted as the distance at which a substance can be processed by the biota (e.g., phosphates), transformed into another compound (e.g., nitrogen compounds) or simply retained by sedimentation or adsorption (e.g., particulate material). Although this information does not, without further study, tell us about the path that each of the compounds produced by the effluent follows, it allows us to evaluate the response; this was observed in the Luján River under two different flow situations, high and low.

## CONCLUSIONS

The use of a discharge of a wastewater treatment plant at a reach without any other affluent or effluent, allowed us to study the capacity of this Pampean river to retain organic and inorganic particulate materials and some nutrients. This showed that, although the river has a capacity to hold and process substances, this is limited since transport distances of the materials considered were comparable to those of other eutrophic rivers studied (between 1 and 4 km) (Martí *et al*., 2004; Haggard *et al*., 2005), but longer than those described in streams (100-500 m) (Martí & Sabater, 1996; Acuña, 2001; Feijoó *et al*., 2011).

The limited self-depuration capacity of the Luján River in conjunction with the wide variety of input of organic matter and nutrients either from concentrated or diffuse sources would require greater distances between the sources than those which exist today. To estimate these distances, different situations of seasonally and high and low flow should be considered. In our study, carried out during summer, a 2-km distance must be considered as the minimum distance before another effluent of nutrients or organic matter is added but, it should also be considered that present management addresses primarily the use of the river for recreation rather than to preserve its ecological functions. So, longer distances would be preferable to preserve ecological and recreational functions.

## ACKNOWLEDGEMENTS

To Dr. G. Romano by the translation into english. This study was done as a thesis project for M. Piccinini. It was supported by PICT Number Nº 0791/11 given to R. Albariño.

## REFERENCES

Acuña, V. (2002). Variacions en el procés de la retenció de nutrients associades al desenvolupament algal en el riu de Perles (Vall d'Alinyà, Alt Urgell). Butlletí de la Institució Catalana D'Historia Natural., **70,** 113-123.

Andrade, M. I. (1986). Factores de deterioro ambiental en la cuenca del Río Luján. Contribución del Instituto de Geografía. Facultad de Filosofía y Letras Universidad de Buenos Aires. Buenos Aires.

APHA. (2005). Standard methods for the examination of water and wastewater. (Washington: American Public Health Association)

Bernot, M. J. and Dodds W. K. (2005). Nitrogen retention, removal, and saturation in lotic ecosystems. Ecosystems., **8,**442-453.

Branco, S. M. (1984). Limnología Sanitaria, Estudio de la Polución de Aguas Continentales. Monografía Nº 28. OEA.

Darley, W. M. (1991). Biología de las algas. Enfoque Fisiológico. Editorial Limusa. Balderas, México.

Domenech, X. (2000). Química de la Hidrósfera. Miraguano Ediciones S. A. Barcelona.

Feijoó, C.; Giorgi, A. and Ferreiro, N. (2011). Phosphorus uptake in a macrophyte-rich Pampean stream Limnologica., **41,** 285-289.

Gordon, N. D., T. A. McMahon, B. L. Finlayson, C. J. Gippel and Nathan R. J. (2004). Stream Hydrology. An Introduction for Ecologists, 2nd ed. John Wiley and Sons, Chichester, UK.

Haggard, B. E.; D. E. Storm and Stanley E. H. (2001). Effect of a point source input on stream nutrient retention. J American Water Res.Assoc. **37 (5),** 1291-1299.

Haggard, B. E.; E. H. Stanley and Storm, D. E. (2005). Nutrient retention in a point-source-enriched stream. J. N. Am. Benthol. Soc., **24 (1),** 29-47.

Heidenwag, I.; U. Langheinrich and Lüderitz, V. (2001). Self-purification in upland and lowland streams. Acta Hydrochim. Hydrobiol., 29 (1), 22-33.

Margalef, R. (1983). Limnología. Ediciones Omega S.A. Barcelona.

Martí, E. and Sabater, F. (1996). High variability in temporal and spatial nutrient retention in Mediterranean streams. Ecology, **77(3),** 834-869.

Marti, E.; Aumatell, J.; Gode, L., Poch, M. and Sabater. F. (2004). Nutrient Retention Efficiency in Streams Receiving Inputs from Wastewater Treatment Plants. J. Environ. Qual., **33,** 285–293.

Navarro, E. (2001). Respuesta ecotoxicológica de comunidades microbentónicas de ríos mediterráneos. Tesis para optar al grado de Doctor en Biología, Departamento de Ecología, Facultad de Biología, Universidad de Barcelona.

Newbold, J.D., J.W. Elwood, R.V. O'Neill and W. VanWinkle. (1981). Measuring nutrient spiraling in streams. Can. J. Fish. Aquat., **38,** 860-863.

Palmeri, F. (2002). Manual de Técnicas de Ingeniería Naturalística en Ámbito Fluvial. Administración de la Comunidad Autónoma del País Vasco, Departamento de Transporte y Obras Públicas.

Rheinheimer, G. (1987). Microbiología de las Aguas. Editorial Acribia S.A. Zaragoza.

Sala J.M., González N. & Kruse E. (1983). Generalización hidrológica de la Provincia de Buenos Aires. Resúmenes Coloquio Internacional sobre Hidrología de Grandes Llanuras, Olavarría, Argentina. Comité Nacional para el Programa Hidrológico Internacional, Buenos Aires, Argentina. pp. 974–1009.

Stream Solute Workshop. (1990). Concepts and methods for assessing solute dynamics in stream ecosystems. J. North Am. Benthol. Soc., **9,** 95-119.

Smith, R. L. and Smith, T. M. (2002). Ecología. Pearson Educación S.A. Editora.