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# Accumulation of Pollutants, Self-purification and Impact on Peripheral Urban Areas: A Case Study in Shantytowns in Argentina

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***Abstract*—**This work sets out to debate the tensions involved in the processes of contamination and self-purification in the urban space, particularly in the streams that run through the Buenos Aires metropolitan area. For much of their course, those streams are piped; their waters do not come into contact with the outdoors until they have reached deeply impoverished urban areas with high levels of environmental contamination. These are peripheral zones that, until thirty years ago, were marshlands and fields. They are now densely populated areas largely lacking in urban infrastructure.

The Cárcova neighborhood, where this project is underway, is in the José León Suárez section of General San Martín county, Buenos Aires province. A stretch of José León Suarez canal crosses the neighborhood. Starting upstream, this canal carries pollutants due to the sewage and industrial waste released into it. Further downstream, in the neighborhood, domestic drainage is poured into the stream. In this paper, we formulate a hypothesis diametrical to the one that holds that these neighborhoods are the primary source of contamination, suggesting instead that in the stretch of the canal that runs through the neighborhood the stream's waters are actually cleaned and the sediments accumulate pollutants. Indeed, the stretches of water that runs through these neighborhoods act as water processing plants for the metropolis.

This project has studied the different organic-load polluting contributions to the water in a certain stretch of the canal, the reduction of that load over the course of the canal, and the incorporation of pollutants into the sediments. We have found that the surface water has considerable ability to self-purify, mostly due to processes of sedimentation and adsorption. The polluting load is accumulated in the sediments where that load stabilizes slowly by means of anaerobic processes. In this study, we also investigated the risks of sediment management and the use of the processes studied here in controlled conditions as tools of environmental restoration.

***Keywords*—**Bioremediation, pollutants, sediments, urban streams.

## I. Introduction

SINCEthe 16th century, the processes of polluting streams and rivers located on the outskirts of cities have been key to the problem of urbanization. The cases of European cities crossed by rivers like the Thames, the Seine, and others are the most well-known. The city of Buenos Aires has suffered as well from the problem of polluted waters, and the "emblematic" case of the Riachuelo emerged early on. As soon as the first *saladeros*, or salted meat processing plants, were established on the banks of the river, the contamination of the river's waters became a concern, albeit a minor one at first [1]. While the problem of pollution may be common to large cities, the responses to it have varied. There have been a number of sometimes contradictory reactions. Not only, though largely, in the metropolises of the global south, we find ourselves five centuries later facing similar, if more advanced, processes of contamination [2]-[4]. Despite the passage of time, the responses are largely the same as they were centuries ago. For that very reason, the effect of environmental decisions both past and present on contemporary life are dramatic.

In the Buenos Aires metropolitan area in particular, it is still common to pipe streams, a river treatment process that basically consists of covering waters followed by constructing on top of the alluvial plain. This practice has countless consequences, including flooding both strictly related, and less strictly related, to it. Similarly, by drastically reducing the time waters circulate, the rectification of rivers limits the purifying capacity of natural riverbeds. Earlier practices that consisted of tossing contamination outside our societies mean we now inhabit cities surrounded by an outside that is, in fact, inside.

What ensues on that outside—those outskirts of the city that, in the 19th century were envisioned as stalking presences—is today a good deal more complex. On the one hand, that outside, especially the alluvial plains it contains, is the permanent site of the increasingly populated poorest neighborhoods in the metropolitan areas. Like a palimpsest, these settlements bear markings of the territory on which they are located, markings that can be traced back to the 19th century [1], [5]. The dynamics are more intense in the present due to a number of questions that can be summarized as the rapid growth of the city which, since the end of the 20th century, has meant a global south characterized by metropolitan areas riddled by more and more precarious living conditions, overcrowding, and environmental decay [6]. On the other hand, there has been a parallel development of gated communities in these outlying areas, urbanized areas that are in many ways tied to settlements that appear to be their polar opposite. Raising water levels and redirecting riverbeds are among the practices that act as a dam to protect certain

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communities while exposing others. Both communities, though, share a geography where that which flowed outward in the 19th century now, in the 21st, flows inwards, generating new problems though not always new solutions [7].

Piping streams continues to be one of the most common solutions offered by urban sanitation engineering. While it may appear to be the simplest solution, the practice of piping has a number of consequences, most of which lead to an increase in pollution in both the neighborhoods where the streams are piped and the rivers into which those piped waters flow.

This, then, is the framework of this study, which sets out to discuss these practices in relation to the tensions involved in processes of contamination and self-purification in the urban space. Here, we pay particular attention to the analysis of streams that, for much of their course, are piped; their waters do not come into contact with the outdoors until they have reached deeply impoverished urban areas with high levels of environmental contamination. These are peripheral zones that, until thirty years ago, were marshlands and fields. They are now densely populated areas largely lacking in urban infrastructure [8].

Located in the José León Suárez area of General San Martín county (see Fig. 1, [9]), the Cárcova neighborhood, where this project is underway, is crossed by a stretch of the José León Suarez canal. Starting upstream, this canal carries pollutants due to the sewage and industrial waste released into it and, further downstream in the neighborhood, due to domestic drainage. In this paper, we formulate a hypothesis diametrical to the one that holds that these neighborhoods are the primary source of contamination, suggesting instead that in the stretch of the canal that runs through the neighborhood, the stream's waters are actually cleaned and the sediments are, in fact, what accumulate pollutants. Indeed, the stretches of water those run through these neighborhoods act as water processing plants for the metropolis.

This project has studied the different organic-load polluting contributions to the water in a certain stretch of the canal, the reduction of that load over the course of the canal, and the incorporation of pollutants into the sediments. We have found that the surface water has considerable ability to self-purify, mostly due to processes of sedimentation and adsorption. The polluting load is accumulated in the sediments where that load stabilizes slowly by means of anaerobic processes. In this study, we also investigated the risks of sediment management and the use of the processes studied here in controlled conditions as tools of environmental restoration.

This project is trans-disciplinary in nature [8]. It approaches the dynamics it studies from a comprehensive perspective that takes into account socio-environmental and urban issues. It is our belief that this work will not only further understanding of the processes it addresses but also facilitate the design of urban-environmental strategies based on options other than simply throwing outside what is found within.

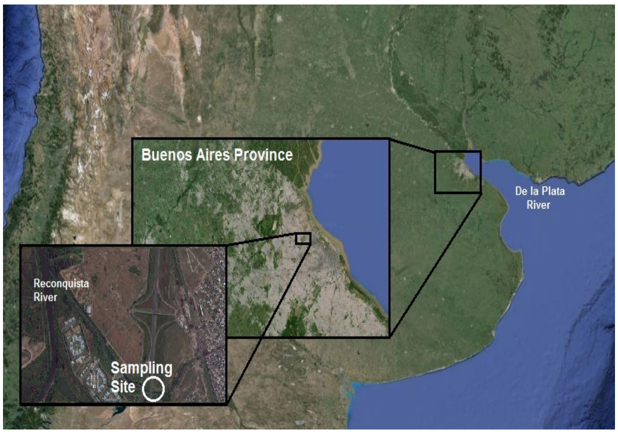


Fig. 1 Location of the studied area (34°31'19.4"S, 58°35'28.0"W)

## II. Methods and Experimental Development

### A. Area of Study and Sample Points

Water samples were taken at various points over the course of the canal, from where it comes into contact with the outdoors (see Fig. 2, point 1 [9]) to where it flows under the Camino BuenAyre bridge (see Fig. 2, point 12).

### B. Description of Pollutants in Waters and Sediments

The sediment samples were collected in 100 ml sterile polypropylene jars. Samples were analyzed before four hours after collection. The following parameters were measured: pH, visible turbidity in a spectrophotometer (620 nm), Chemical Oxygen Demand (COD) [10], and number of coliforms by dilution in DEV and EMB agar plates.

The sediment samples were collected and stored at 4ºC in polypropylene jars. The samples initial level of humidity was preserved so that the redox conditions at the time of collection would vary as little as possible.

The Walkley Black method [11] was used to determine relative humidity by gravimetry and the content of oxidizable organic matter. The purge and trap method for acid volatile sulfide was used to determine the content of soluble sulfides in MS type acid (M denotes bivalent metals like Fe(II) and Zn(II)). This process was followed by methylene blue conversion [12], [13]. Prior to that process, an estimate of the quantity of carbonates in the sample was arrived at by means of the Kemess Fiss Rating [14]. The standard sequential extraction of metals procedure recommended by the Community Bureau of Reference, known as the BCR extraction [15], was performed to determine the concentration and distribution of metals in different components of sediment (Fraction 1: associated with carbonates and silicates; Fraction 2: associated with Mn and Fe oxidants; Fraction 3: associated with sulfides and organic matter; Fraction 4: residual). The concentration of Cu, Zn, and Fe was determined by means of Atomic Absorption Spectroscopy (AAS).

Acidification risk and metal release were determined in situ according to the methodology formulated by Kersten and Förstner (K&F) [16].

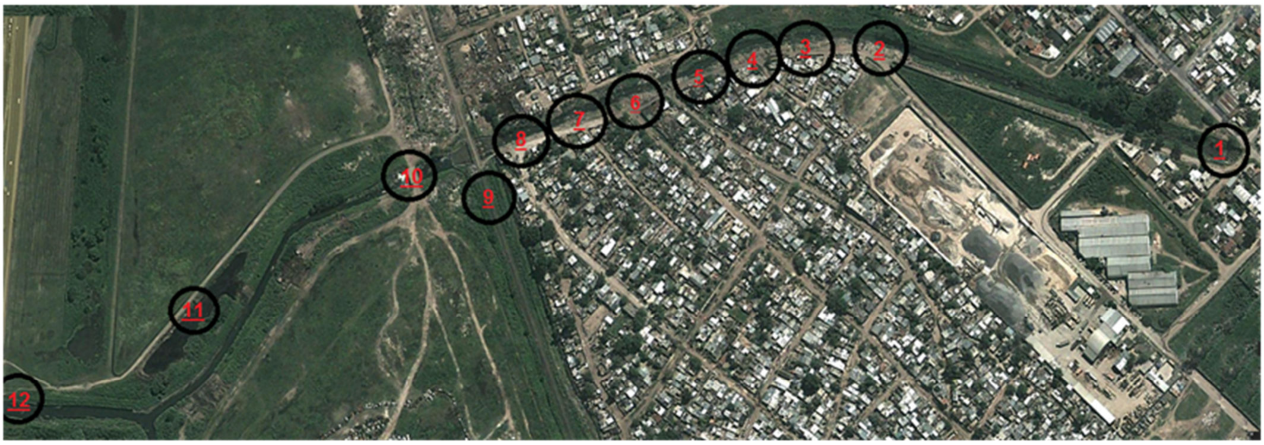


Fig. 2 Enlarged image of the area studied. The contribution of another canal coming from an adjacent neighborhood (Curita neighborhood) is observed between points 11 and 12

## III. Results

### *A. Typical Parameters of Sewage Contamination*

Table I shows results of parameters indicative of contamination such as organic load (COD), pH, turbidity, and coliform bacteria found in the waters analyzed. Points 6, 8, and 11 are taken from the water released in the neighborhood (points 6 and 8) and from a lagoon formed by illegal dumping (point 11) rather than from the riverbed. The lagoon and the canal come into contact only pursuant to intense rains. Point 10 marks where the stream leaves the neighborhood.

TABLE I
Parameters Analyzed in Samples Taken at Points 1-12 on the Map

| | pH | Turbidity | COD (mg/L) | Coliform count (UFC/mL) |
|---|---|---|---|---|
| 1 | 7.92 | 0.297 | 200.22 | 1.03E+12 |
| 2 | 7.67 | 0.038 | <50 | ND |
| 3 | 7.79 | 0.044 | <50 | ND |
| 4 | 7.84 | 0.060 | 48,00 | ND |
| 5 | 7.72 | 0.020 | <50 | ND |
| 6 | 7.49 | 0.132 | 172.44 | ND |
| 7 | 7.82 | 0.027 | <50 | 5.50E+04 |
| 8 | 7.54 | 0.085 | 59.11 | 1.80E+08 |
| 9 | 7.58 | 0.022 | <50 | ND |
| 10 | 7.71 | 0.016 | <50 | 1.80E+08 |
| 11 | 7.81 | 0.479 | <50 | 2.80E+05 |
| 12 | 7.83 | 0.055 | 99.11 | 1.36E+05 |

ND: not determined

On the basis of the information in Table I, it appears that when the water enters the neighborhood it is dirtier than when it leaves and that turbidity is closely associated with organic load. When the stream enters the neighborhood, its organic load is 200 mg/L and its coliform population around $10^{12}$ colony-forming units/mL (CFU), which indicates fecal contamination. There are leaks of sewage and—according to previous studies [17], [18]—industrial waste into the rainwater pipe that runs under Italia Avenue in the urbanized areas of José León Suarez.

Both the organic load and the enterobacteria population diminish quickly less than 100 meters away from the neighborhood's sewage pipe, the former falling to values below 50 mg/L and the latter to $10^4$CFU/mL. This stretch of the stream is where sediment accumulates copiously on the riverbed. The organic load of the substances released into the stream as it flows through the neighborhood is lower than the overall load of the stream when comes into the neighborhood and very low in volume. Hence, the canal's organic load is not increased along this stretch, due to the effect of the dilution and to the aforementioned stabilization process. At point 12, the organic load once again increases due to confluence with the canal from Villa Curita marked in Fig. 2.

The data obtained here suggests that the water in this stream have a rapid process of self-purification. This self-purification process has a much greater speed than that expected by conventional oxidation process studied in "classic" sanitary engineering and it is attributable mainly to the physicochemical mechanisms of precipitation and adsorption.

When the water leaves the neighborhood (at point 10), its organic load is very low and its concentration of coliforms stands at $10^8$, or eight times less than when it enters. Nonetheless, the level of oxygen dissolved into the water over this entire stretch of the stream was less than 2 mg/L at 20°C (25% saturation) and, at some points, close to zero. This effect, which may be surprising at first, is related to the great benthic oxygen demand generated by the canal's sediments which, due to their highly reductive traits, consume dissolved oxygen, generating anaerobic reactions to stabilize the excess of organic matter. Table II shows the contribution of colloidal material conveyed by the water into the system's organic load.

TABLE II
Values of COD (mg/L) in the Surface Water of the Sediment Column, Water with Suspended Sediment, and That Same Water After Filtering

| Sediment Samples | COD Surface Water (centrifuged) | COD Water with Suspended Sediment | COD Filtered Water |
|---|---|---|---|
| 1 | <50 | 395 | 200 |
| 8 | <50 | 550 | 59 |
| 11 | <50 | 3212 | <50 |
| 12 | <50 | 99 | 46 |

The extremely high purification rate observed in the canal can be attributed in part to the rapid sedimentation and adsorption of the particulate material carried by the water in the canal's sediments. This sedimentation does not occur in the areas where the current flows quickly such as where the canal first comes into contact with the outdoors (or as would occur in the areas with piping), which means that the pollutants flow downstream.

### *B. Analysis of Sediments*

Table III shows the parameters obtained pursuant to the analysis of sediment samples from points 8, 10, 11, and 12.

The extremely high concentration of organic matter and of sulfides in the sediments clearly indicate that organic contamination quickly latches onto the sediment as suggested by the data on the reduction of contamination in the waters.

This high concentration of organic matter is stabilized by biocatalyzed reactions. As the concentration of dissolved oxygen diminishes, anaerobic microorganisms begin to generate sulfides that let off the stench for which the stream is known.

TABLE III
INITIAL DESCRIPTION OF SEDIMENTS AT POINTS 8, 10, 11, AND 12

| Sediment sample | pH | % Humidity | % Organic matter | AVS (mg/kg) | Zn (mg/kg) |
|---|---|---|---|---|---|
| 8 | 7.69 | 54.33 | 13 | 81 | 218 |
| 10 | 7.80 | 55.27 | 50 | 292.8 | ND |
| 11 | 8.13 | 30.88 | > 80 | 152 | 801 |
| 12 | 6.78 | 41.73 | 12 | 685 | 339 |

AVS: Acid volatile sulphides; ND: Not determined.

It has been determined [19] that a change in the redox conditions of the sediments of the sort produced by inadequate dredging can lead to acid drainage and the release of metals into the water column. For this reason, it is necessary to perform accurate analyses before embarking on any action that entails, for instance, the dredging of streams and rivers.

### *C. Parameters of Industrial Contamination: Heavy Metals in Sediments*

It is very difficult to determine contamination of water due to industrial waste. Contamination of this sort is indicated mostly by heavy metals which do not readily dissolve in neutral pH conditions. Furthermore, the dumping of industrial waste tends to be irregular, as opposed to continuous, and randomly performed at unlikely times of day to avoid detection. Nonetheless, the quick incorporation and accumulation of metals and other recalcitrant pollutants in sediments suggest a history of dumping over a long period of time. The results on the concentration of metals found in the canal studied (sample point 10) are shown in Table IV.

TABLE IV
INITIAL HEAVY METAL CONTENT IN THE SEDIMENTS OF THE CANAL

| | Cadmium(mg/kg) | Chromium(mg/kg) | Copper (mg/kg) | Zinc (mg/kg) |
|---|---|---|---|---|
| Sample 10 | 11.4 | 60.4 | 220 | 1468 |
| Sample12 | ND | 56 | 113 | 419 |

ND: Not determined.

According to international quality guidelines [20]-[22], all of these levels of contamination are above benchmark levels or in the range of low effects. In some cases, they exceed the level of intervention and/or display a truly troubling toxicological level. Some metals, like zinc and cadmium, are above the high effect threshold, indicating likelihood of adverse environmental effects on benthic microorganisms. In the case of all four metals studied the level of contamination falls into the "very contaminated" category according to the benchmarks used by the INA in studies of sediments in the Paraguay-Parana waterway.

These results clearly indicate industrial contamination that comes into the neighborhood's sediments from upstream in the rainwater collection system that has leaks due to illegal dumping. Metals were not detected in the sediments in the drainage canals that run through the neighborhood carrying domestic waste into the canal (samples 6 and 8).

The concentration of metals in the sediments diminishes as the canal moves away from the neighborhood. This suggests that, while the tributary that flows into the canal between sample points 10 and 12 contains a high organic load (see Table I), it does not carry heavy metals. The sole source of those metals is upstream waters channeled by the "rainwater" collection stream under Italia Avenue.

### *D. Potential Restoration*

The stabilization of organic matter ensues through the adsorption, sedimentation, and formation of insoluble species like the sulfides and hydroxides found in heavy metals. This is how pollutants collect in sediments.

Many of the reactions involved in these processes are biocatalyzed and, in controlled conditions, they could be used to restore the sediments. Candal et al. [19] isolated from the stream microbial species (*Actinobacteria, Rahnella*) with great ability to perform biosorption and biodegradation of colorants also detected in the canal.

Porzionato et al. [23], [24] isolated sulfide-reducing microbial species and oxidation sulphur that, if used in isolated sediments, can remedy contamination by heavy metals through a process of bioleaching.

Thus, if maintenance work is undertaken (landscaping the banks of the canal, removing waste, enacting security measures, etc.) the canal could continue to act as a virtual water processing plant while sediments are treated where pollutants are collected in controlled conditions. This treatment can be carried out by stimulating biocatalyzed processes performed by native microorganisms that can even contribute to reducing levels of metals.

## IV. CONCLUSION

The contamination of streams and rivers in cities is nothing new and, due to many of the actions undertaken—as well as the failure to take action—living at the banks of a body of water in a city is increasingly dangerous. As discussed in this work and in previous studies, the processes of dredging often undertaken as a way of reducing contamination only serve to stir up the pollution that lies dormant in sediments, thus aggravating the problem those processes hoped to remedy. Similarly, the piping of stream waters and the construction over them has had, and continues to have, a direct effect on the experiences of inhabiting and circulating in the city. Like a Moebius strip, in the 21st century these covered canals, as well as urban spaces, that were once on the outskirts of the city now form an integral part of the city's dynamics.

This work gives rise to a number of questions, some of which it is important to formulate here. First, the study of the stream articulates and evidences the geopolitical position of neighborhoods largely lacking in urban infrastructure and, hence, subject to environmental decay. In terms of the stream, this means high levels of pollutants that reach the neighborhood in piped waters that the stream, once in contact with the outdoors, purifies while, like memory, leaving traces of the polluting sediments in the neighborhood. This means that the water is cleaned but the contamination remains. In other words, in the neighborhood the piped stream becomes a natural sewage treatment plant and, when it leaves, it is once again a stream.

This process demonstrates in and of itself how the beds of rivers and streams in contact with the outdoors and not subject to any rectification play a key role in purifying contamination; by means of the biocatalyzed processes discussed above, this purification can lead to processes that mitigate contamination and, thus, improve living conditions.

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