

Identification and environmental significance of organic pollutants and heavy metal contaminants found in storm water, urban runoff and domestic sewage channels, discharging to the Matanza-Riachuelo Basin, Argentina 1997

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Introduction

The Matanza-Riachuelo Basin runs through a highly industrial and urbanised area of Argentina, to the south of the city of Buenos Aires. Sections of both rivers are already highly polluted, yet they continue to receive unknown quantities of industrial waste, domestic sewage and urban runoff. A recent report to the press by the Argentine Secretary of Natural resources and Sustainable Development (Programa de Obras 1997), listed domestic sewage, and wastes generated from the chemical, petrochemical, pharmaceutical, metallurgical, leather, food, textile and paper industries, as the primary contributors and sources of the pollution.

In November 1997, thirteen samples of storm water, urban runoff, domestic sewage and sediment were collected from channels discharging into the Matanza-Riachuelo Basin, with the aim of identifying the range of organic pollutants and heavy metal contaminants present (see Table 1).

All samples were collected and stored in glass bottles, previously rinsed with nitric acid and pentane, to remove all heavy metal and organic residues (Keith 1991). Solid samples were collected with wooden spoons, previously rinsed with deionised water, nitric acid and pentane. Aqueous samples were collected in 1-litre bottles, rinsed three times with the sample before the final collection. Bottles were filled completely, ensuring no air bubbles were present. They were then transported to the Greenpeace Research Laboratory, kept cold during transit, and refrigerated immediately on arrival. Organic compounds were identified qualitatively using Gas Chromatography Mass Spectrometry (GC-MS). Heavy metals were determined quantitatively using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES).

Sample Number	Sample Type	Sample Description
AG7007	Sediment	Collected from the sewage system, Chacabuco and Dean Funes, Avellaneda
AG7014	Effluent	Collected from storm water / urban runoff pipe discharging into the Cildanez River, Lanus
AG7015	Sediment	See AG7014
AG7018	Effluent	Collected from storm water / urban runoff channel, close to the De Maio tannery, Lanus
AG7019	Sediment	See AG7018
AG7021	Effluent	Collected from storm water / urban runoff channel, discharging into the Riachuelo River below the Valentin Alsina Bridge, Lanus
AG7022	Sediment	See AG7021
AG7023	Sediment	Collected at storm water / urban runoff / Riachuelo River confluence, Cnel. Milan Street / Calle de la Ribera Sur Str., Lanus
AG7028	Effluent	Collected from storm water / urban runoff channel as it enters the Matanza River, Belgrano Trail Bridge, La Matanza
AG7033	Effluent	Collected from storm water / urban runoff channel as it enters the Riachuelo River, Buenos Aires
AG7034	Effluent	Collected from storm water / urban runoff channel as it enters the Riachuelo River, Lomas de Zamora
AG7045	Effluent	Collected from storm water / urban runoff channel as it enters the Matanza River, La Matanza
AG7055	Effluent	Collected from storm water / urban runoff channel as it enters the Arroyo Santo Domingo / Rio de la Plata, Avellaneda

Table 1 Descriptions of samples collected from the Matanza-Riachuelo Basin, Argentina 1997

Materials and Methods

1. Organic Screen Analysis

All solvents were of High Purity Grade (PRAG or low haloform). Glassware used in extraction and cleaning up procedures was cleaned in detergent, rinsed with tap water and deionised water, dried in the oven overnight at 105⁰C, and rinsed three times with low haloform pentane.

Solid Samples

For each sample, approximately 30g (wet weight) was weighed and transferred to a clean 100 ml glass bottle. Samples were spiked with deuterated (d8) naphthalene (an internal standard) at a concentration of 4.7 mg/kg. 15 ml of pentane was added, followed by 5 ml of acetone. All samples were then sonicated for 2 hours.

Extracts were decanted, filtered through a pre-cleaned hydrophobic phase separator filter and collected in reagent tubes. They were then acidified to pH 2 with 10% nitric acid. Following this, a second portion of 15 ml pentane / 5ml acetone was added and the extraction procedure repeated. Finally, both extracts obtained for each sample were combined and evaporated to a

volume of approximately 3 ml. The concentrated extract was cleaned through Florisil column, eluted with a 95:5 mixture of pentane:toluene, and evaporated down to a volume 2 ml under a stream of analytical-grade nitrogen. 1-bromonaphthalene was then added as a marker.

Aqueous Samples

Prior to the extraction, samples were spiked with deuterated (d8) naphthalene (an internal standard) at a concentration of 150 ug/l. 20 ml of pentane was added, and the sample agitated for 2 hours on a bottle roller to maximise contact between solvent and sample.

After separation of the phases, the solvent extract was filtered through a hydrophobic phase separator filter and collected in pre-cleaned reagent tube. The aqueous sample was acidified to pH 2 with 10% nitric acid, a second portion of 20 ml pentane was added and the extraction procedure repeated. The clean-up procedure was as for solid samples.

Chromatographic Analysis

Samples were analysed using a Hewlett Packard (HP) 5890 Series II gas chromatograph, interfaced with a HP ChemStation data system, and linked to a HP 5972 Mass Selective Detector operated in scan mode. The identification of compounds was carried out by computer matching against a HP Wiley 275 library of 270,000 mass spectra. Results are reported as a list of those compounds reliably and tentatively identified. Match qualities of 90% or greater are assumed to give reliable identifications; tentative identification refers to qualities between 51% and 90%. Analytes yielding match qualities of 50% or less are assumed to be unidentified.

2. Heavy Metal Analysis

Solid Samples

Samples were dried in an oven for 48 hours, until dry weight readings became constant. They were then crushed using a pestle and mortar until homogenous and sieved through a 2 mm mesh. 0.5 g of sample was weighed into a 120 ml Teflon microwave vessel fitted with a screw cap and pressure relief valve. To this 10 ml of deionised water was added, followed by 7.5 ml of concentrated hydrochloric acid and 2.5 ml of concentrated nitric acid. The vessels were then sealed, placed on a rotating table in a microwave oven (model MDS-2000, CEM Corp.), and allowed to digest for one hour at full power (630 W).

After cooling to ambient temperature, the digests were filtered into volumetric flasks, diluted with deionised water, made up to a volume of 50 ml and mixed. A Standard Reference Material, PACS-1 (trace elements in marine sediment), certified by the National Research Council, Canada, and a blank sample, were prepared with each batch of 10 samples. All were prepared in 15% v/v hydrochloric acid and 5% v/v nitric acid.

Aqueous Samples

Water samples were preserved in 5% v/v nitric acid on arrival. 50 ml was transferred to a 120 ml Teflon microwave vessel and digested using the same procedure and programming conditions described above. After cooling to ambient temperature, samples were filtered into volumetric flasks, diluted with deionised water, made up to a volume of 50 ml and mixed. A quality control standard (internally prepared at a concentration of 8.0 mg/l) and a blank

sample were prepared with each batch of ten samples. Both were prepared in 5% v/v nitric acid.

ICP-AES Analysis

Following preparation, all samples were analysed by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES), using a Varian Liberty-100 Sequential Spectrometer. The following metals were quantified directly: manganese (Mn), chromium (Cr), zinc (Zn), copper (Cu), lead (Pb), nickel (Ni), cobalt (Co) and cadmium (Cd). A multi-element instrument calibration standard was prepared at a concentration of 10 mg/l (matrix matched to the samples). The calibration was validated using a quality control standard, prepared from different reagent stocks, at 8 mg/l. Samples exceeding the calibration range were diluted appropriately, in duplicate, and re-analysed. The spectrometer was re-calibrated after twenty samples to adjust for fluctuations in sensitivity.

Mercury (Hg) was determined using Cold Vapour Generation ICP-AES. Mercury (II) was reduced to mercury (0) i.e. a vapour, following reduction of the samples with sodium borohydride (0.6% w/v), sodium hydroxide (0.5% w/v) and hydrochloric acid (10 molar). The vapour was carried in a stream of argon into the spectrometer. Two calibration standards were prepared, at 10 ug/l and 100 ug/l (matrix matched to the samples). Samples exceeding this range were diluted and re-analysed. The quality control standard was again prepared from a different reagent stock at 80% of the calibration range (i.e. 80 ug/l). The spectrometer was re-calibrated after every 10 samples.

Reporting limits of 0.01 mg/l were used for all metals with the exception of lead (0.03 mg/l) and mercury (0.002 mg/l). These were calculated using statistical methods supplied by the UK Water Research Centre (1989).

Results

Results are given in Tables 2-4

Sample Number	Mn (ppm)	Cr (ppm)	Zn (ppm)	Cu (ppm)	Pb (ppm)	Ni (ppm)	Co (ppm)	Cd (ppm)	Hg (ppm)
Sediments									
AG7007	98.0	211.8	276.5	839.2	163.7	22.6	3.9	n/d	0.7
AG7015	236.3	36.3	261.8	79.4	253.9	12.8	4.9	n/d	0.2
AG7019	199.0	8192.3	115.4	69.2	30.8	5.8	1.0	n/d	0.4
AG7022	220.4	1764.3	1144.9	295.2	261.2	40.8	7.1	2.0	2.2
AG7023	48.2	441.8	109.1	23.6	20.9	n/d	0.9	n/d	0.3
Effluents									
AG7014	0.25	<0.01	0.33	<0.01	<0.03	<0.01	<0.01	<0.01	<0.002
AG7018	0.58	0.04	0.24	0.08	<0.03	0.01	<0.01	<0.01	<0.002
AG7021	0.26	0.11	0.08	0.01	<0.03	<0.01	<0.01	<0.01	<0.002
AG7028	0.22	<0.01	0.17	0.01	<0.03	<0.01	<0.01	<0.01	<0.002
AG7033	0.13	<0.01	0.09	0.02	<0.03	<0.01	<0.01	<0.01	<0.002
AG7034	0.23	0.11	0.09	0.06	<0.03	<0.01	<0.01	<0.01	<0.002
AG7045	0.41	<0.01	0.02	0.03	<0.03	<0.01	<0.01	<0.01	<0.002
AG7055	0.26	<0.01	0.20	0.01	<0.03	<0.01	<0.01	<0.01	<0.002

Table 2 Results of heavy metals analysis, Matanza-Riachuelo Basin area Argentina 1997

Table 2 shows the results of the heavy metals analysis. Results are expressed in ppm (parts per million, i.e. mg/kg dry-weight for sediments, mg/l for effluents). They show that significant levels of chromium, zinc, copper, lead, cadmium and mercury were found in some samples.

Sediment levels of chromium ranged from 36.3 mg/kg in sample AG7015, to 8192.3 mg/kg in sample AG7019, the latter collected close to the De Maio tannery, in the district of Lanus. Chromium levels in uncontaminated sediment are usually less than 50 mg/kg (Salomons and Forstner 1984). When we compare this value with the results above, we see that of the five sediment samples collected, four contained levels of chromium indicative of contamination (AG7007, AG7019, AG7022, AG7023), with sample AG7019 containing levels over 150 times greater than those usually associated with clean sediments. Whilst the others contained between 4 and 35 times background levels.

Sediment levels of zinc ranged from 109.1 mg/kg in sample AG7023, to 1144.9 in AG7022. Background levels of zinc in sediment are usually quoted as being less than 100 mg/kg (Salomons and Forstner 1984). Thus comparisons with published levels and our results suggest elevated levels of zinc in samples AG7007, AG7015 and AG7022. Sample AG7022 containing levels 10 times greater than those usually associated with clean sediments.

Sediment levels of copper ranged from 23.6 mg/kg in sample AG7023 to 839.2 mg/kg in AG7007. Background levels of copper in sediment are usually quoted as being less than 50 mg/kg (Salomons and Forstner 1984). Thus comparisons with published levels and our results suggest elevated levels of copper in samples AG7007 and AG7022. Sample AG7007 containing levels over 15 times higher than those usually associated with clean sediments.

Sediment levels of lead ranged from 20.9 mg/kg in sample AG7023 to 261.2 mg/kg in AG7022. Background levels of lead in sediments are usually quoted as being less than 50 mg/kg (Salomons and Forstner 1984). Thus comparisons with published data and our results suggest elevated levels of lead in samples AG7007, AG7015 and AG7022, with levels in AG7015 and AG7022 five times greater than those usually associated with clean sediments.

In addition, slightly elevated levels of cadmium and mercury were found in sample AG7022. 2.0 mg/kg of cadmium were detected and 2.2 mg/kg of mercury. Background levels are usually quoted as being <1 mg/kg and <0.5 mg/kg respectively (Salomons and Forstner 1984).

Effluent concentrations of these metals were generally low, however detectable levels of manganese and zinc were found in all samples, copper was found in all samples with the exception of AG7014, chromium was found in samples AG7014, AG7021 and AG7034, and nickel was found in sample AG7018.

Table 3 shows the groups of organic compounds reliably identified in each of the samples. Figure 1 shows the number of samples containing compounds from each group, expressed as a percentage. The most abundantly identified organic compounds were polycyclic aromatic hydrocarbons (PAHs), most notably naphthalene and its derivatives, found in nearly 70% of the samples; followed by aliphatic hydrocarbons, found in over 60% of the samples. Organohalogenes and alkylbenzenes were found in four of the samples (31%). The most commonly identified organohalogenes being isomers of dichlorobenzene. In addition, three of the samples (23%) contained other aromatic compounds such as indene derivatives and other derivatives of benzene, and two of the samples contained molecular sulphur and / or organo-sulphur compounds. Finally, one sample (AG7034) contained four phenol derivatives,

including nonyl-phenol and 2,6-bis-(1,1-dimethylethyl)-4-methyl-phenol, also known as butylated hydroxytoluene.

Groups of compounds identified to better than 90%	Number of samples	Sample codes
ORGANOHALOGENS		
DDT	1	AG7033
DDD	1	AG7007
Dichlorobenzenes	4	AG7007, AG7014, AG7021, AG7033
POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)		
Anthracene and derivatives	1	AG7019
Fluorene and derivatives	1	AG7019
Naphthalene and derivatives	8	AG7007, AG7014, AG7018, AG7019, AG7022, AG7023, AG7028, AG7055
Phenanthrene and derivatives	2	AG7014, AG7019
Azulene and derivatives	1	AG7019
PHENOL DERIVATIVES		
Nonyl-phenol	1	AG7034
4, Methyl-phenol	1	AG7034
4-(2,2,4-Trimethylpentyl)-phenol	1	AG7034
2,6-Bis-(1,1-dimethylethyl)-4-methyl-phenol	1	AG7034
ALKYL BENZENES		
	4	AG7014, AG7018, AG7028, AG7034
OTHER AROMATICS		
Indene and derivatives	2	AG7014, AG7015
Benzene derivatives (not already listed)	2	AG7015, AG7055
SULPHUR AND ORGANO-SULPHUR COMPOUNDS		
	2	AG7018, AG7034
STERIODS AND TERPENOIDS		
	1	AG7034
ALIPHATIC HYDROCARBONS		
	8	AG7014, AG7015, AG7019, AG7022, AG7023, AG7033, AG7034, AG7055

Table 3 Groups of organic compounds reliably identified in samples collected from storm water, urban runoff and sewage channels, Matanza-Riachuelo Basin, Argentina 1997

Figure 1 Occurrence (in %) of groups of organic compounds found in runoff and sediment samples collected from the Matanza-Riachuelo River Basin area, Argentina 1997

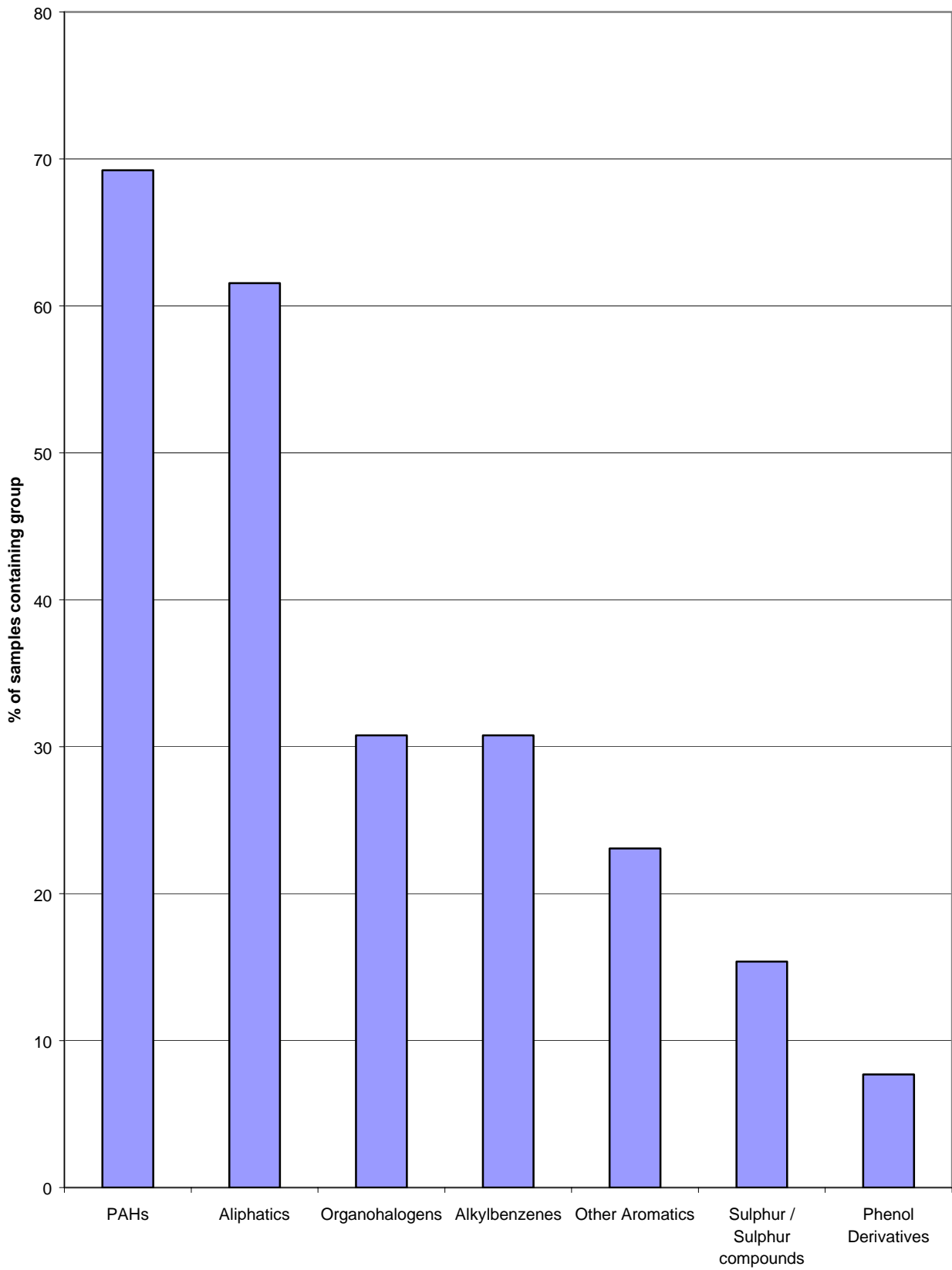


Table 4 shows the number and types of organic compounds reliably identified in each of the samples. The percentage of reliably identified compounds ranged from zero (sample AG7045) to 48% (sample AG7034).

Sample Number	Number of Compounds Isolated	Reliably Identified	Number of Halogenated Compounds	Number of PAHs	Number of Alkylbenzenes	Number of other Aromatics	Number of Aliphatics
AG7007	78	7 (9%)	2	5	0	0	0
AG7014	90	31 (34%)	1	8	5	3	14
AG7015	21	4 (19%)	0	0	0	3	1
AG7018	29	10 (34%)	0	2	7	0	0
AG7019	90	26 (29%)	0	13	0		13
AG7021	46	2 (4%)	2	0	0	0	0
AG7022	48	9 (19%)	0	1	0	0	8
AG7023	45	17 (38%)	0	3	0	0	14
AG7028	9	2 (22%)	0	1	1	0	0
AG7033	30	9 (30%)	2	0	0	0	7
AG7034	42	20 (48%)	0	4	3	5	6
AG7045	5	0	0	0	0	0	0
AG7055	41	10 (24%)	0	6	0	1	3

Table 4 Results of organic screening analysis, Matanza-Riachuelo Basin, Argentina 1997

Discussion

Note: for uses, toxicological data and environmental significance of contaminants found, refer to Part 1 (Environmental Samples) and Part 2 (Industrial Samples) of this report.

Rio Matanza

The Rio Matanza passes through the rural districts of Canuelas, General Las Heras and Marcos Paz, in the upper part of the basin area; then through the slightly more industrial and urban districts of Ezeiza, Esteban Echeverria, La Matanza and Lomas de Zamora, after which it becomes the Riachuelo. Two samples of effluent were collected from two storm water / runoff channels discharging into the Rio Matanza in the district of La Matanza, AG7028 and AG7045. These samples were amongst the cleanest collected, with low levels of heavy metals detected (manganese, zinc and copper) in both samples, and naphthalene (PAH) and one alkylbenzene reliably identified in sample AG7028.

Riachuelo

The Riachuelo passes through the districts of Lomas de Zamora, Lanus, Buenos Aires and Avellaneda, and eleven samples were collected from storm water, runoff and sewage channels, discharging into its waters.

1. Lomas de Zamora (AG7034)

One sample of effluent was collected from a storm water / urban runoff channel discharging into the Riachuelo in the district of Lomas de Zamora (AG7034), close to the speedway, downstream of environmental sample AG7011. Sample AG7011 contained high levels of chromium, suggesting that the channel may also be used to carry industrial wastes, notably from tanneries. It also contained high levels of lead, zinc and copper, major components of domestic sewage and urban runoff (Stephenson 1988).

Sample AG7034 contained detectable levels of manganese, chromium, zinc and copper. In addition, polycyclic aromatic hydrocarbons (naphthalene derivatives), alkylbenzenes, phenol derivatives (including nonylphenol), steroids, organo-sulphur compounds and long chain aliphatic hydrocarbons were all reliably identified. Many of these compounds are frequently used as tracers to identify contamination caused by domestic sewage and / or petroleum products (see Part 1 Environmental Samples). In addition, the relatively high concentration of chromium in the effluent compared to the other metals found, does suggest that tannery waste is being carried along this channel and discharged into the Riachuelo.

2. Buenos Aires (AG7033)

One sample of yellow effluent (pH 5) was collected from a storm water / urban runoff channel discharging into the Riachuelo in the district of Buenos Aires City. Although collected in a different district, sample AG7033 was also taken close to the speedway mentioned above. Levels of heavy metals were low, with only manganese and zinc present at detectable concentrations. However, organic screening analysis of this sample revealed the presence of DDT and 1,4-dichlorobenzene. The area is highly industrialised and densely urban, thus the sources of these two persistent organic pollutants could be numerous. 1,4-dichlorobenzene is most frequently used as a toilet deodoriser; thus its presence could be an indication that domestic sewage is being discharged along this channel. DDT is more difficult to source. It has been widely used to control insects on agricultural crops and insects that carry diseases such as malaria and typhus (ATSDR 1997), however it is now banned in most of the world, except in cases of public health emergency. Although use in a number of South American, African and Asian countries continues (see Part 2 Industrial Samples).

3. Lanus (AG7014, AG7015, AG7018, AG7019, AG7021, AG7022 and AG7023)

Seven samples of effluent and sediment were collected from storm water and urban runoff channels discharging into the Riachuelo in the district of Lanus.

All the effluent samples (AG7014, AG7018, and AG7021) contained detectable levels of manganese and zinc. In addition chromium and copper were found in samples AG7018, close to the De Maio tannery, and AG7021. With low levels of nickel being found in sample AG7018. Manganese and zinc are both major components of domestic sewage. They can also be present in urban runoff, both from tyres, and manganese from the organo-manganese compound MMT, used as an anti-knock additive in unleaded petrol. Chromium, found in AG7018 and AG7021, is commonly used as a leather tanning agent, thus its presence in these samples suggests that tannery waste is being discharged along these storm water / runoff channels. The location of the De Maio tannery in the vicinity of sampling sites AG7018 and AG7019 further indicates that this is the case. Although low levels were detected in effluent sample AG7018 (no discharge was observed at the time of sampling), anomalously high levels were found in sediment sample AG7019.

Regarding organic pollutants, sample AG7014 contained 90 isolated compounds. Those reliably identified included 1,2-dichlorobenzene, naphthalene and eight of its derivatives, phenanthrene alkylbenzenes, long chain aliphatic hydrocarbons, and indene derivatives. Again, this combination of pollutants suggests the discharge of untreated domestic sewage and / or petroleum contamination (urban runoff). Similar compounds were identified in sample AG7018 (seven alkylbenzenes, naphthalene and a derivative and molecular sulphur) and sample AG7021 (two reliably identified isomers of dichlorobenzene).

In general, the sediment samples (AG7015, AG7019, AG7022 and AG7023) collected from this district were even more contaminated than the effluents, as most metals and many persistent organic pollutants discharged into the environment will bind predominantly to suspended material before finally accumulating in the sediment. Thus the analysis of sediment provides a reliable history of pollution within a given area.

Sample AG7015 was collected from a pipe discharging into the Cildanez River, and contained elevated levels of zinc and lead, both major components of urban runoff, and in the case of zinc, of domestic sewage. In addition, a number of aromatic compounds were reliably identified including two indene derivatives.

Sample AG7019 was collected from a storm water / runoff channel, also used to carry and discharge tannery waste from the De Maio tannery. This sample contained an anomalously high level of chromium, over 160 times greater than levels usually found in unpolluted sediments (Salomons and Forstner 1984). In addition, the PAHs naphthalene, fluorene, anthracene and phenanthrene (and derivatives) were all reliably identified, along with a large number of long chain aliphatic hydrocarbons.

Sample AG7022, collected close to effluent sample AG7021 in which chromium and isomers of dichlorobenzene were reliably found, contained anomalously high levels of chromium, zinc, copper, lead, cadmium and mercury. Comparisons with published data suggest that this is heavily contaminated sediment with respect to these metals (Salomons and Forstner). In addition, naphthalene and a number of long chain aliphatic hydrocarbons were also reliably identified.

Sample AG7023 was also collected from a storm water / runoff channel discharging into the Riachuelo river in an urban region of Lanus. Again chromium levels are high, eight times greater than concentrations usually associated with clean sediments (Salomons and Forstner 1984). In addition, naphthalene derivatives and a large number of long chain aliphatic hydrocarbons were also reliably identified.

4. Avellaneda (AG7007 and AG7055)

Two samples were collected from two different channels discharging into the Riachuelo River in the district of Avellaneda. Sediment sample AG7007 was collected from a sewage channel also believed to carry industrial wastes and urban runoff. Heavy metals analysis of this sample seems to confirm this, as high levels of chromium, zinc, copper and lead were detected. In addition, DDD, 1,2-dichlorobenzene and 5 derivatives of naphthalene were reliably identified.

Effluent sample AG7055 was collected from a storm water / urban runoff channel discharging into the Arroyo Santo Domingo. Manganese, zinc and copper were present at detectable concentrations. In addition, naphthalene and 5 of its derivatives, along with a number of long chain aliphatic hydrocarbons were also reliably identified.

Conclusion

Our analysis has highlighted the presence of a wide range of anthropogenically derived chemicals, including a large number of heavy metal contaminants and organic pollutants often found in untreated sewage, urban runoff and industrial wastes. What is evident from many of the results is that domestic sewage, urban runoff and industrial wastes (especially

from tanneries) are being carried along storm water channels discharging into the Riachuelo-Matanza Basin.

As discussed in both the Environmental and Industrial Sample Reports, many of these heavy metals and organic compounds are toxic at very low concentrations and have the potential to bioaccumulate. Many of the compounds found are also highly persistent, and therefore even if discharges ceased in the very near future, retention by sediments (as shown) and soils, animal and human tissues, would delay the elimination of this contamination for many years.

The continued discharge of domestic sewage, urban runoff, and industrial wastes along storm water channels must be addressed. As at present, and in the past, these channels are acting as significant sources of toxic and persistent chemicals in the basin. For this practice to cease, the bodies accountable for sewage treatment and water quality, and the industries themselves, must take full financial and legal responsibility for this contamination, and for the preservation of the environment in this region.

As emphasized in both Parts 1 and 2 of this report, long-term solutions based on clean production alternatives, renewable resources and pollution prevention need to be employed. For as long as the current situation is not addressed, and clean production practices are not forthcoming, more widespread decay of the Matanza-Riachuelo basin cannot be avoided.

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