Water Quality Indicators for the La Plata River Basin

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ABSTRACT Selected water quality data from La Plata River Basin shared by 5 South-American countries (Argentina, Bolivia, Brazil, Paraguay and Uruguay) was employed to evaluate advantages and constraints for global water quality indicators development. Water quality state indicators from UNSD/UNEP Questionnaire (2004) were considered at 5 sampling stations located on the Paraná (3), Pilcomayo and La Plata Rivers. Water pollution pressure indicators, also called driving forces, were estimated for the main emissions from the Metropolitan Area of Buenos Aires into the La Plata River. Multiple and different monitoring programs and operating agencies limited the availability of continuous time series of water quality indicators for this large river basin. Further development of water pollution pressure and technological indicators is required to improve cause-effect water quality follow up. Attention was given to the need to develop criteria for censored data statistics (mostly related with toxics constituents), and to establish tools to assess, periodically, the state of water environments through water quality guidelines, standards and risks to the biota through the usage of potency factors.

La Plata River Basin General Water Statistics

The La Plata River Basin with a drainage area of 3100000 km^2 is the second largest in South America (UNEP, 2004) and among the five largest in the world. It drains 694770 Hm^3 of water into the Atlantic Ocean with a mean discharge of 22031 m^3 /s. This river watershed covers five countries (Argentina, Bolivia, Brazil, Paraguay and Uruguay). The corresponding drainage area in Argentina is 918000 km^2. Water withdrawals for domestic, industrial, and agricultural uses in these five countries are presented in Table 1.

Table 1 Percentage of annual water withdrawals for the main consumptive uses in the countries of the La Plata River Basin (GWP-SAMTAC, 2000)

Country	Domestic (%)	Industrial (%)	Agricultural (%)
Argentina	9	18	73
Bolivia	10	5	85
Brazil	22	19	59
Paraguay	15	7	78
Uruguay	6	3	91

More than 70 hydropower plants were installed in the basin. Among them, joint international ventures, like Itaipú (12600 Mw) and Yacyretá (2700 Mw) are relevant examples. The Paraná-Paraguay waterway allows barges navigation along 3400 km. Sites for the Governments of four of these countries are located within the La Plata River Basin (Asunción del Paraguay, Brasilia, Buenos Aires and Montevideo). Various rivers of this basin are drinking water sources for large cities (San Pablo, Brasilia, Buenos Aires, Curitiba and Rosario).

La Plata River Basin supply 85% of argentine water resources; giving a per capita availability of 22500 m^3 /s (World Bank,1995) .Only 10% of argentine sewage water is

treated , against a figure of 38% in Brazil, based on plain costs constraints and a mistaken assumption of complete and rapid self-purification capacity of these large water courses.

Water Quality State Indicators

UNSD/UNEP Questionnaire on Environment Statistics (2004) demands information on water quality of selected rivers, lakes, and coastal areas as measured in selected measuring stations. Stating that the selection of water bodies should be based on their national (economic, demographic, geographic and hydrologic) importance and the quantity and quality of available measurements. The selection of the measuring station should be based on the availability of longer time series of measurements. Water quality "categories" identified by UNS/UNEP are: annual average flow (rivers), biochemical oxygen demand (BOD5), dissolved oxygen (DO), chemical oxygen demand (COD), total dissolved solids (TDS), total phosphorus (TP), total nitrogen (TN) and faecal coliforms. It also allows the addition of other categories.

Three water quality monitoring stations located on the Paraná River (2 stations along the argentine –paraguayean reach), one on the Pilcomayo River (Misión La Paz, argentine - paraguayean reach) and one on Rio de la Plata argentine shore, were selected in order to show water quality indicators temporal evolution (1990- 2004). They are depicted on Figures 1 to 5.On left hand ordinates ,in logarithmic scale , water quality categories (W6) with concentrations in mg/L are presented, on the right hand ordinates faecal coliforms (MPN/100mL) and dissolved metals concentrations (μg/L) are quantified. The records of BOD5 in the Paraná River water show that this category might not be a relevant indicator, due to concentrations near the method detection limit, for assessing organic matter pollution in very large rivers. Thus, the main organic and nitrogen carbon water constituents are present as humic substances, not easily biodegradable. Only measurements on river banks, under raw domestic and industrial effluents plumes, are able to detect the effect of urban BOD5 loads. Murtinho Port (Brazil), in the upper Paraguay River, was the sole case reported with BOD5 concentrations quite over 2 ppm (UNEP, 2004). These higher BOD5 concentrations in the Paraguay River are explained by significant organic loads entering from Southern Matto Grosso State, Brazil, under important agricultural development.

In the case of the Pilcomayo River, particulates concentration (TSS) is the main water quality indicator, not only for their high concentrations and direct environmental impact on river channel siltation, but also for their relevance on the transport of metals borne tailing wastes from mining areas in the upper basin (Bolivian Andes) into the lower basin (argentine-paraguayean Chaco). Particulates render metals less bioavailable for the aquatic biota, thus reducing their toxic effects (Natale, et. al., 2004). Dissolved toxics constituents, both inorganic (metals) and persistent organic pollutants (POP´s) present frequent records under the method detection limit, nevertheless they are relevant water quality indicators for assuring the protection of living organisms (humans and aquatic biota). To deal with this censored data various criteria may be used (assume indicator concentration equal to zero, or equal to the method detection limit or equal to one order of magnitude lower than the detection limit, etc). A standard criterion ought to be established for this purpose. Metals need additional supplementary water quality categories (pH, major ions, and dissolved organic carbon) in order to estimate their toxic effects to aquatic biota (Di Toro, D.M.; et. al., 2000). Acidification processes from mining activities and acid rain also need the usage

of pH as a relevant water quality category. The National Water Agency from Brazil operates 32 water quality monitoring stations within the La Plata River basin (ANA,2004). Five basic categories (pH, temperature, DO, turbidity and conductivity) are automatically monitored. And up to 54 physicochemical and bacteriological parameters, including nutrients TDS and BOD5, are also monitored with varied frequencies (bimonthly, quarterly, biannual and annual).These Brazilian water quality indicators are available at the HIDRO Data Bank (www.ana.gov.br/hidroweb). Brazilian states employ USA National Sanitation Foundation water quality index for the aggregating of water quality state indicators of their river courses But they are not used in the remaining countries of the La Plata River Basin.
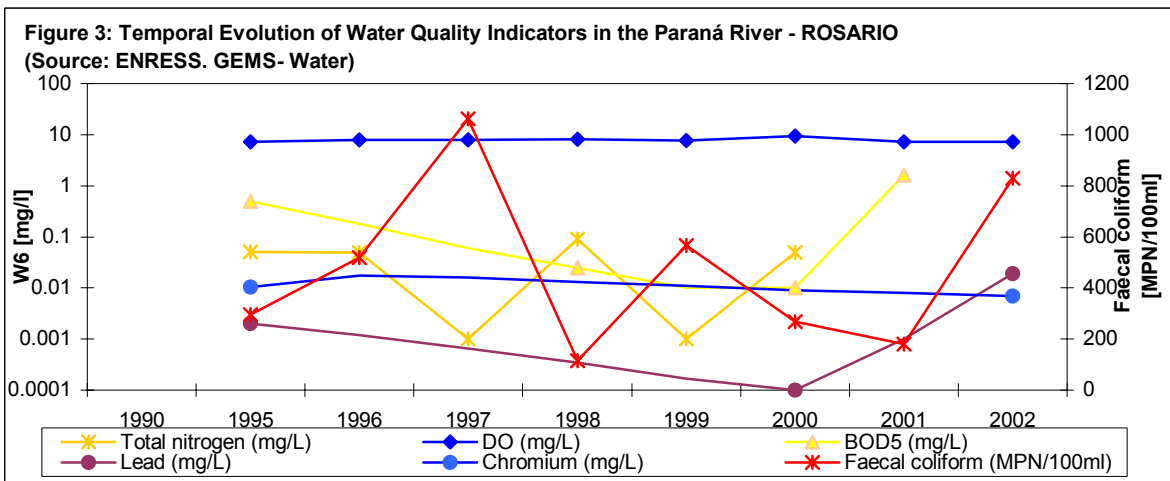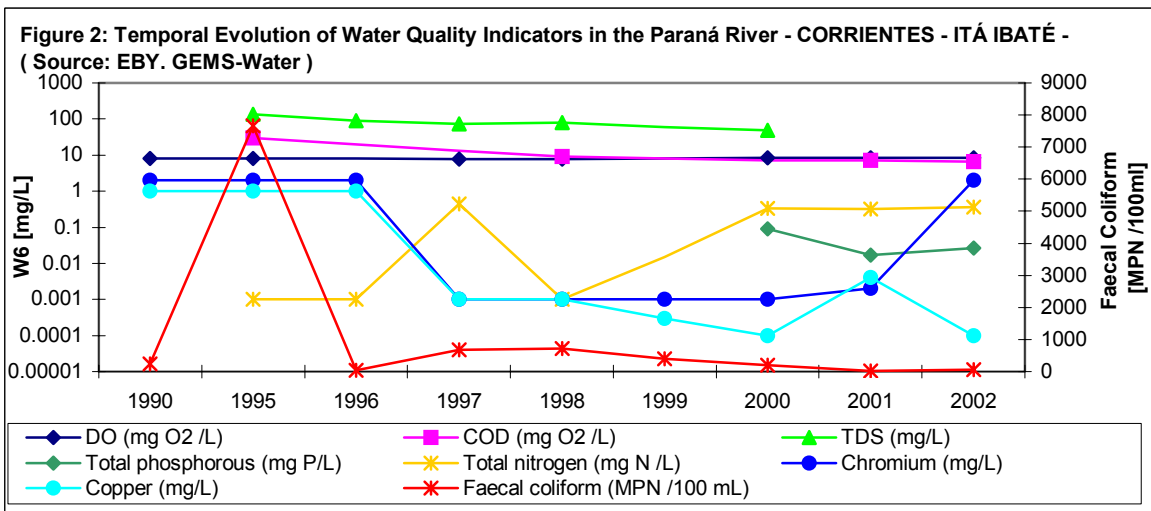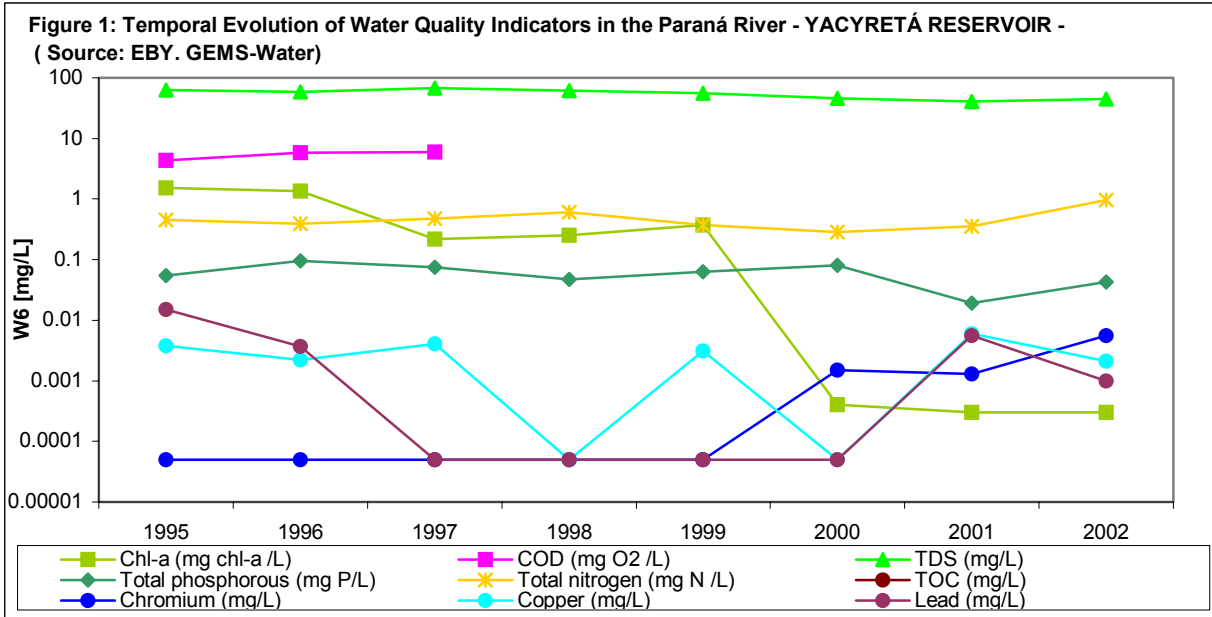
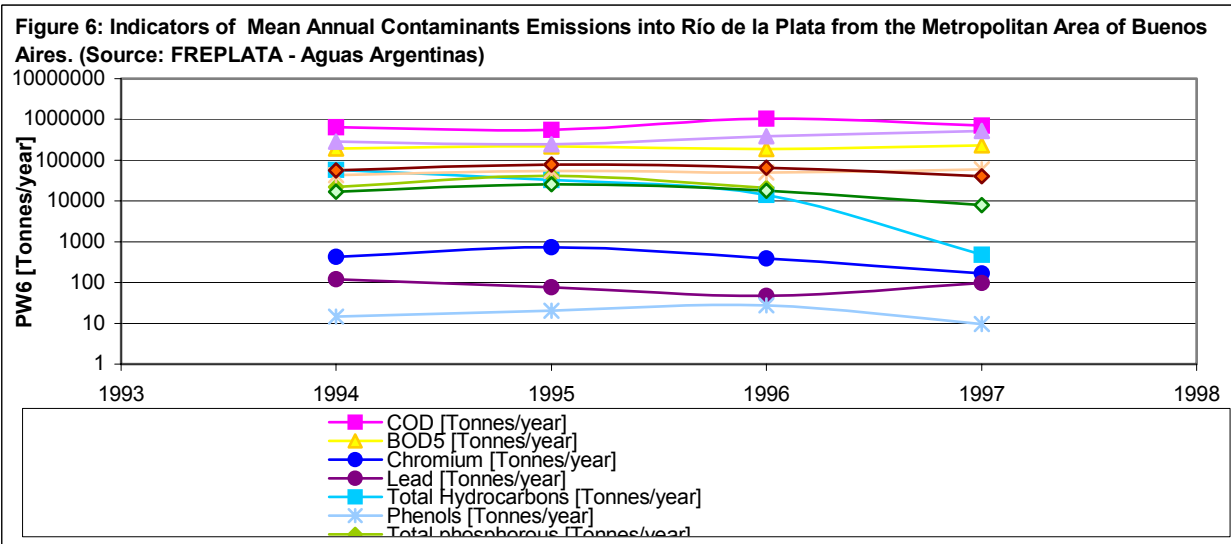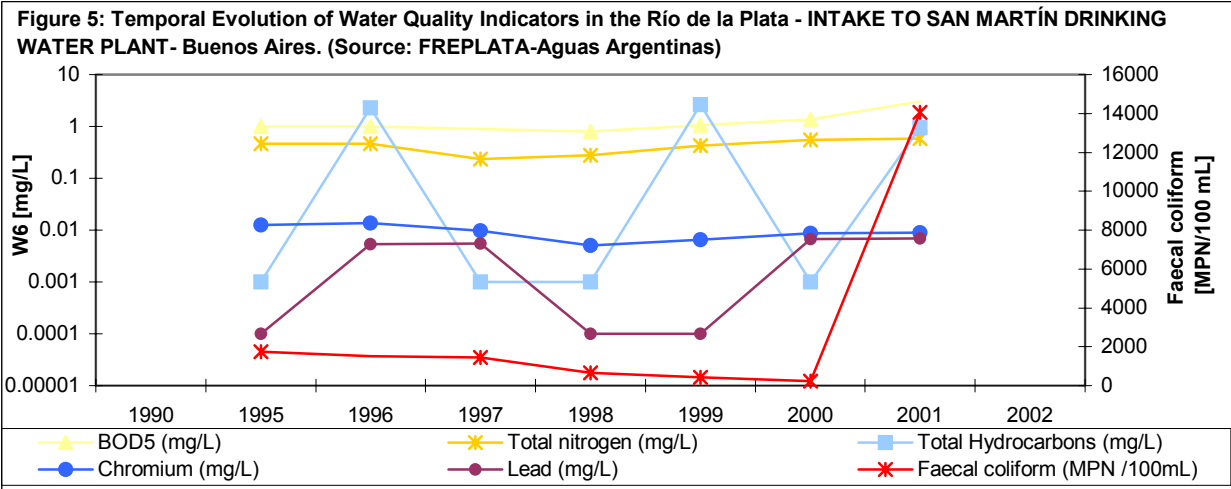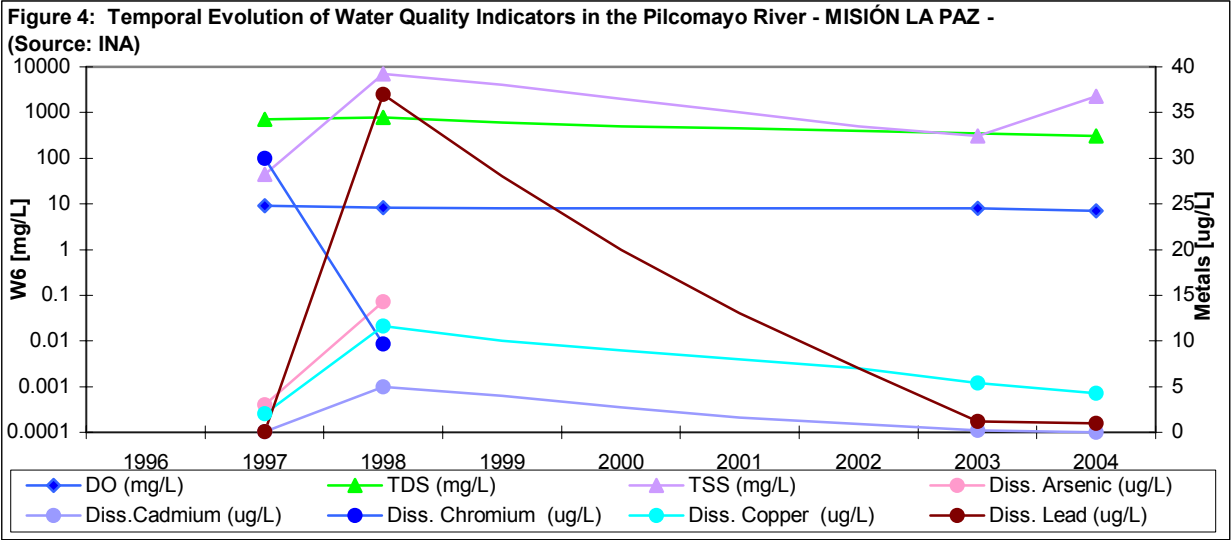## Water Pollution Pressure Indicators (Driving Forces)

UNSD/UNEP Questionnaire on Environment Statistics (2004) employs a general water pollution pressure indicator: total wastewater generated (W4A) . This water pollution pressure indicator is further refined by indicators that determine the degree and kind of processes employed for wastewater treatment (mechanical, biological, advanced), type of treatment plants (POWTP and industrial). The significance of the percentage of water treated is stated by EPI-TEPI as the " reflection of both the pressure of human activities on the water resources, both quantitatively and qualitatively, and the society´ s response to wastewater treatment and the protection of health and ecosystems". The percentage of wastewater treated is linked by EPI-TEPI to other pressure indicators that include quality of emissions. A total sewage sludge production (10^3 tons) is the category employed to assess other environmental stresses (to land or air). These categories do not allow a quality characterization of the water pollution pressures. Take note that a significant amount of toxics are scarcely removed by conventional treatment facilities.

For the La Plata River Basin annual pollution loads from the Metropolitan Area of Buenos Aires (MABsAs) discharged into Rio de La Plata are presented in Figure 6. Mass loads of BOD5, COD, metals (Cr, Pb) ,Total phenols, Total Hydrocarbons , TN, TP and TDS, discharged through polluted rivers (Lujan, Riachuelo), channels (Sarandí, Santo Domingo) , sewage outfall (Berazategui) , storm outfalls and creeks were taken into consideration. These rivers, channels, and creeks are receiving sewage and industrial wastewaters so they represent the integration of pollutants loads from thousands of industrial activities (tanneries, slaughter houses, chemical, petrochemical, and metal plating processes, etc) and raw and biologically treated sewage. Under present conditions they do not have relevant water uses and are considered as water pollution pressures to Rio de la Plata. They may be employed as estimators subject to direct contaminants mass monitoring instead of indirect waste loads estimators of contaminants emissions from urban activities.

Indicators of Water Burdens or Risks from Emissions to Water Resources

Water Pollution Pressure Indicators proposed by UNSD/UNEP and EPI-TEPI are able to show temporal evolution of various categories without allowing a major synthesis among categories to assess water burdens or risks to the aquatic biota and human health. Various approaches for estimating a continuous assessment of water burdens and risks from emissions may be employed. They incorporate an effect factor also called

**Figure 1: Temporal Evolution of Water Quality Indicators in the Paraná River - YACYRETÁ RESERVOIR -
(Source: EBY. GEMS-Water)**

Legend:
- Chl-a (mg chl-a /L)
- COD (mg O2 /L)
- TDS (mg/L)
- Total phosphorous (mg P/L)
- Total nitrogen (mg N /L)
- TOC (mg/L)
- Chromium (mg/L)
- Copper (mg/L)
- Lead (mg/L)

**Figure 2: Temporal Evolution of Water Quality Indicators in the Paraná River - CORRIENTES - ITÁ IBATÉ -
(Source: EBY. GEMS-Water)**

Legend:
- DO (mg O2 /L)
- COD (mg O2 /L)
- TDS (mg/L)
- Total phosphorous (mg P/L)
- Total nitrogen (mg N /L)
- Chromium (mg/L)
- Copper (mg/L)
- Faecal coliform (MPN /100 mL)

**Figure 3: Temporal Evolution of Water Quality Indicators in the Paraná River - ROSARIO
(Source: ENRESS. GEMS- Water)**

Legend:
- Total nitrogen (mg/L)
- DO (mg/L)
- BOD5 (mg/L)
- Lead (mg/L)
- Chromium (mg/L)
- Faecal coliform (MPN/100ml)

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Figure 4: Temporal Evolution of Water Quality Indicators in the Pilcomayo River - MISIÓN LA PAZ - (Source: INA)

Legend: DO (mg/L); TDS (mg/L); TSS (mg/L); Diss. Arsenic (ug/L); Diss.Cadmium (ug/L); Diss. Chromium (ug/L); Diss. Copper (ug/L); Diss. Lead (ug/L)

Figure 5: Temporal Evolution of Water Quality Indicators in the Río de la Plata - INTAKE TO SAN MARTÍN DRINKING WATER PLANT- Buenos Aires. (Source: FREPLATA-Aguas Argentinas)

Legend: BOD5 (mg/L); Total nitrogen (mg/L); Total Hydrocarbons (mg/L); Chromium (mg/L); Lead (mg/L); Faecal coliform (MPN /100mL)

Figure 6: Indicators of Mean Annual Contaminants Emissions into Río de la Plata from the Metropolitan Area of Buenos Aires. (Source: FREPLATA - Aguas Argentinas)

Legend: COD [Tonnes/year]; BOD5 [Tonnes/year]; Chromium [Tonnes/year]; Lead [Tonnes/year]; Total Hydrocarbons [Tonnes/year]; Phenols [Tonnes/year]; Total phosphorous [Tonnes/year]

potency factor that takes into account environmental and human health burdens and risks, such as potential toxicity to biota and eutrophication. The mathematical form of this type of indicator is: Σ PFi .Ei., where PFi is the Potency Factor (PF) that measures the effect or risk of the emission of constituent "i" (Ei) in the ambient compartment of interest, freshwater in our case. The usage of Potency Factors allows the normalization and aggregation of the pertinent water quality indicators to show the overall burden or risk to water resources. Various developments are available to estimate these Potency Factors, mainly to estimate toxicity potentials of metals and persistent organic pollutants (POP´s) in the frame of life cycle analysis (LCA) (Huijbregts, 1999) and analysis of risk assessment methods for POP´s (Zhang, et. al.; 2001); and also to assess environmentally sustainable technologies by employing metrics capable of estimating water burdens (acidification, oxygen demand, ecotoxicity and eutrophication)due to industrial emissions (ICHEME). In the case of risk characterizations the PF incorporates normalized factors to take into account constituents fate and transport (persistence, environmental partitioning) by employing various models; biota exposure to them (bioavailability and bioconcentration); and their toxic effects (acute or chronic to living organisms: humans, environmental biota). The normalizing constituent, or reference substance, employed by various authors to assess risks due to emissions varies, thus Zhang and collaborators employ different reference substances to take into account toxicity to aquatic biota and toxicity to humans (non carcinogenic and carcinogenic). Huijbregts, on the other hand, employs only one reference substance 1,4-dichlobenzene (1,4 DCB) for humans and biota, and all the environmental compartments. To estimate the aggregated water burdens and risks to Rio de la Plata due to emissions of some toxics (chromium, lead and phenols) and nutrients (nitrogen, phosphorus and COD) from the Buenos Aires Metropolitan Area, Huijbregts and ICHEME approaches were used, for toxicity and eutrophication assessment, respectively. Table 2 and Figure 6 present the water burdens (eutrophication and risks potentials) for Río de la Plata, expressed in Tonnes of equivalent reference substance per year. This assessment was performed with the pertinent mean annual toxics and nutrients loads previously estimated. Table 2 shows that freshwater toxicity potentials (in Tonnes of 1,4 DCB equivalents/year) , due to emissions from the MABsAs into Rio de La Plata, are one or two orders of magnitude larger than water pressures produced by metals and phenols present in these emissions. On the other hand eutrophication burdens to the Rio de la Plata (in Tonnes of P/year) are reduced in comparison with the respective MABsAs nutrients emissions values. Thus water burdens and risks indicators not only allow a synthesis of water pressure indicators but mainly a better assessment of water pollution effects.

CONSTITUENT (i)	POTENCY FACTOR	EFFECT (Reference Constituents)	CONSTITUENTS EMISSIONS (Ei) [Tonnes / year]				WATER BURDENS [Tonnes equivalent reference c. /year]			
			1994	1995	1996	1997	1994	1995	1996	1997
CHROMIUM (Cr +6)	28.0	Freshwater Aquatic Biota Toxicity (1,4 DCB)	432	724	384	163	12096	20272	10752	4564
LEAD (Pb)	9.6	Freshwater Aquatic Biota Toxicity (1,4 DCB)	120	76	47	98	1152	730	451	941
TOTAL PHENOLS (PHENOL)	240.0	Freshwater Aquatic Biota Toxicity	15	20	28	10	3600	4800	6720	2400

Table 2: Indicators of Fresh Water Burdens / Risks from the Metropolitan Area of Buenos Aires Emissions into Río de la Plata

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		(1,4 DCB)								
$\sum_{i=1}^{n} FAETP_i \times E_i$	--	Freshwater Aquatic Biota Toxicity (1,4 DCB equiv.)	--	--	--	--	16848	25802	17923	7905
TOTAL NITROGEN (TN)	0.4	Eutrophication (P)	43306	55242	50061	58972	18189	23202	21026	24768
TOTAL PHOSPHOROUS (TP)	1.0	Eutrophication (P)	21930	41670	20796	--	21930	41670	20796	--
CHEMICAL OXYGEN DEMAND (COD)	0.022	Eutrophication (P)	705495	631716	1068748	718258	15521	13898	23512	15802
$\sum_{i=1}^{n} PFEUTRO)_i \times E_i$	--	Eutrophication (Phosohorous equivalents)	--	--	--	--	55639	78769	65334	40570

Conclusions and Recommendations

After this brief presentation of water quality indicators applied to the La Plata River Basin, mainly focused on argentine water courses, we may conclude that some UNSD/UNEP water quality state indicators like BOD5 might not be responsive or sensible enough to show the effect of anthropogenic organic loads outside of the local impact zone of the discharged wastewaters. On the other hand the total suspended solids (TSS) is a relevant water quality indicator for rivers subject to siltation and conveying significant amounts of toxic substances, reducing their bioavailability. Multiple and differently oriented monitoring programs and operating agencies constraint the availability of continuous time series of water quality indicators for the La Plata River Basin. Fortunately a CIC/UNEP/OAS/GEF-WB supported project, presently developed in the basin, is expected to improve water quality monitoring and pollution assessment activities. Additional criteria is suggested to complement the UNSD/UNEP rationale for selecting water bodies for indicators development , mainly nationally oriented, in order be able to cover water quality indicators at locations to deal with basin scale approaches to monitor the abatement of persistent toxics and other long range transported pollution. The establishment of criteria to deal with non detections, mainly for toxics water quality indicators is required. Water quality pressure indicators, based on measured or estimated wastewater loads, are also recommended for point and non point sources in order to be able to follow up the temporal evolution of cause-effect relationships. Finally the development of aggregated water burdens or risks indicators (toxicity potentials to aquatic biota and humans, eutrophication potential, acidification potentials, etc) is recommended. Criteria should be established (approach, models, reference substances, potency factors) to compute these water quality burdens and risks.

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