Freshwater Contamination (Proceedings of Rabat Symposium S4, April-May 1997).
IAHS Publ. no. 243, 1997

Presenting the GEMS-GLORI, a compendium of world river discharge to the oceans

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Abstract The GEMS-GLORI register, circulated by UNEP for review in 1996, lists 555 world major rivers discharging to oceans ($Q > 10$ km^3 year^{-1}, or $A > 10\,000$ km^2, or sediment discharge $>$ 5Mt year^{-1}, or basin population >5M people). Up to 48 river attributes are listed, including major ions and nutrients (C, N, P) in both dissolved, particulate, organic and inorganic forms. For many rivers, two or three sets of data are provided with relevant periods of records and references. Although half of the selected rivers are not yet documented for water quality, most of the first 40 rivers are well described (Irrawady, Zambezi, Ogooue, Magdalena, are noted exceptions). Altogether about 10 000 individual data from 500 references are listed. The global coverage in terms of river discharge and/or drainage area ranges from 40 to 67% for most major water quality attributes but drops to 25% for some organic and/or particulate forms of N and P. Planned development of the register includes collection of information on particulate chemistry and data on endorheic rivers and selected tributaries.

INTRODUCTION

Fluvial transport provides unique information on processes and rates of chemical weathering and mechanical erosion, (Walling & Webb, 1983; Meybeck, 1996). Water quality is also an integrated indicator of global environmental change and of local and regional environmental pollution impacts (Meybeck *et al.*, 1989). The Global Water Quality Monitoring Programme of UNEP/WHO/UNESCO/WMO, GEMS/WATER, was the first programme of its kind to address global issues of water quality through a network of monitoring stations in rivers and other water bodies on all continents (Fraser *et al.*, 1995). Recognizing the large quantity of pollutants carried from the land by rivers, the GEMS/WATER programme agreed to collect and to systematize published documentation on river fluxes to oceans. Early attempts were undertaken by Clarke (1924) and by IAHS (Durum *et al.*, 1960), Livingstone (1963) and UNESCO in the 1970s. The latter included a World Register of River Inputs (WORRI), and several contributions to the UNEP Regional Seas programme prepared for the Mediterranean, the Gulf of Guinea, the Caribbean and the Southeast Asian Seas. Considering the growing demand for riverine data (GESAMP, 1987), a new global register named GLORI (Global River Index), listing *c.* 1000 rivers with their basic river basin characteristics, total suspended solids and total dissolved solids, was issued by IGBP/LOICZ in April 1995 (Milliman *et al.*, 1995). In parallel, as agreed between IGBP/LOICZ and GEMS/WATER, another register was established on somewhat expanded grounds by the authors of the present paper (Meybeck & Ragu, 1996). This register, known as the GEMS/WATER Global Register of Rivers Inputs (GEMS-GLORI), is the first contribution made by this programme to the land-based sources issue.

DATA SOURCES

General sources

As of June 1995. general sources of data included:

(i) Official yearbooks (water discharge and water quality) for individual countries, or state of the environment reports.

(ii) UN agencies reports, e.g.:
Unesco River Discharges (UNESCO, 1971),
UNEP/UNESCO Regional Seas Reports,
River discharges by the Global Runoff Data Center, (WMO, Koblenz),
Former WORRI register (UNEP/UNESCO).

(iii) Specific books on global hydrology, e.g.:
World Water Balance and Water Resources of the World, (Korzun, 1978),
Water Resources of the World (Van der Leeden, 1975),
Biogeochemistry of Major World Rivers (Degens *et al.*, 1991).

(iv) GEMS/Water programme — the Global data bank managed at the WHO Collaborating Center, Burlington, Canada by A. Fraser and E. Ongley, has provided long term median values for about 90 river stations at the river mouth.

(v) Scientific literature found in books and symposia.

(vi) Previous reviews — those on a global or a regional scale (Livingstone, 1963; Milliman & Meade, 1983; Milliman & Syvitski, 1992; Meybeck, 1979) were also considered. Special attention was paid to rivers draining the land area of the former Soviet Union, because of its large size, and to the reviews of Georgievski *et al.* (1997), Tsirkunov *et al.* (1997) and Gordeev & Tsirkunov (1997), also published by Gordeev *et al.* (1996), which were given priority.

A major source is the Mitteilungen of the Geological and Palaeontological Institute of Hamburg University which hosted and published the results of the UNEP/SCOPE programme "Transport of Carbon and Minerals in Major World Rivers" called SCOPE Carbon which lasted more than 10 years under the direction of the late Egon Degens (Degens *et al.*, 1991).

River discharges and basin area

For this information, ORSTOM (Office de la Recherche Scientifique et Technique d'Outre Mer, Paris) reports for Africa and some South American countries were also considered in addition to the previously mentioned references. Local reports, such as that of Rao (1979) for India, were also used at the national scale. Since many rivers are now affected by damming, irrigation or diversion, the natural discharges have been distinguished from the actual, i.e. modified, discharge.

Suspended load

These data came mostly from the review by Milliman & Syvitski (1992). Whenever these authors mentioned two significantly different figures, actual loads were separated from the natural ones measured prior to the building of major dams. For Soviet rivers, data reviewed by Georgievski *et al.* (1997) and Gordeev & Tsirkunov (1997) were preferred. Earlier reviews by UNESCO and IAHS in the 1960s and 1970s were also used.

Major ions and total dissolved solids (TDS)

Total dissolved solids are calculated as the sum of major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, HCO_3^{-}) plus dissolved silica (expressed as SiO_2) when available. The TDS is an indication of the level of water mineralization. These data, as well as those for Dissolved Inorganic Carbon (DIC, essentially present in river waters as HCO_3^{-}), come from very diverse sources collected by many scientists. National reports were also collected and used (i.e. Canada, France, Germany, Finland, Spain, Turkey).

Carbon and nutrients

The GEMS/Water programme also provided DIC and nutrients near the river mouth for about 90 rivers. These are median values for the whole period of record, generally 10 years (the water discharge-weighted averages are not yet available). Beyond the SCOPE Carbon publications, most carbon and nutrients analyses, such as particulate nitrogen, particulate phosphorus and even dissolved organic carbon which are rarely performed in regular surveys, have been found in scientific publications.

All relevant source publications (*c.* 500 references) are listed in two Annexes in both chronological and alphabetical order.

SELECTION OF RIVERS

Criteria for inclusion

The following criteria were used to determine which rivers were included in the compendium:

(i) Rivers discharging to oceans — no rivers discharging to internal regions were included in this first phase of the compilation (e.g. Volga, Chari, Amu Darya were excluded).

(ii) Drainage area >10 000 km^2 — in some regions, the drainage area can be very loosely defined. As a result, only the largest basins are included in semi-arid regions where runoff is less than 1 l s^{-1} km^{-2} or 30 mm $year^{-1}$ as in Somalia, and northeastern and eastern Australia. Therefore, many relatively small river basins (10 000 to 50 000 km^2) that are not permanent (e.g. oueds, wadis, arroyos, etc.) may be missing (e.g. in Peru, southern Argentina, Namibia, Somalia, eastern and northeastern Australia, etc.). When the average runoff is less than 0.1 l s^{-1} km^{-2} (3 mm $year^{-1}$), the surface runoff is not organized and drainage area data are generally absent. Such basins are considered as arheic. Regions with these characteristics (e.g. Mauritania, parts of Arabia, etc.) are generally aggregated by geographers (such as the Soviet geographers) with the truly endorheic basins.

Table 1 Structure of the GEMS-GLORI database.

Descriptor		Abbreviation	Units
Location and basin characteristics (Annex VIII)	River name	River	see Table I,
	Country of river month	Country	II, III
	Ocean & regional sea at river mouth	Ocean	see Table VI
	Continent of river basin	Cont.	
	Latitude	Lat.	
	Longitude	Long.	
	Average basin temperature	*T*	°C
	Average basin precipitation	*P*	mm $year^{-1}$
	Total river length	*L*	km
Suspended and dissolved loads (Annex IX)	Basin area	A	Mkm^2
	Average natural water discharge	*Qnat*	km^3 $year^{-1}$
	Average actual water discharge	*Qact*	km^3 $year^{-1}$
	Average runoff (1) (*)	**q1*	mm $year^{-1}$
	Average specific discharge (*)	**q2*	$l\ s^{-1}\ km^{-2}$
	Natural suspended load	*Msnat*	Mt $year^{-1}$
	Actual suspended load	*Msact*	Mt $year^{-1}$
	Total dissolved load (2) (*)	**Md*	Mt $year^{-1}$
	Total suspended solids (3) (*)	*TSS	mg l^{-1}
	Total dissolved solids (4) (*)	*TDS	mg l^{-1}
Dissolved nutrients (Annex X)	Dissolved silica	SiO_2	mg SiO_2 l^{-1}
	Nitrate	$N\text{-}NO_3^-$	mg N l^{-1}
	Ammonia	$N\text{-}NH_4^+$	mg N l^{-1}
	Orthophosphate	$P\text{-}PO_4^{-3}$	mg N l^{-1}
	Dissolved organic phosphorus	DOP	mg P l^{-1}
	Dissolved organic nitrogen	DON	mg N l^{-1}
	Dissolved organic carbon	DOC	mg C l^{-1}
	Dissolved inorganic carbon (*) (5)	*DIC	mg C l^{-1}
	Total dissolved carbon (6) (*)	*TDC	mg C l^{-1}
Particulate and total nutrients (Annex XI)	Particulate organic carbon (7)	*POC	mg C l^{-1}
	Dissolved + particulate organic carbon (8)	*DOC+POC	mg C l^{-1}
	Total organic carbon (9)	TOC	mg C l^{-1}
	Total nitrogen (10)	TN	mg N l^{-1}
	Total phosphorus (9)	TP	mg P l^{-1}
	Particulate inorganic carbon	PIC	µg g^{-1}
	Particulate organic carbon (15)	POC	µg g^{-1}
	Particulate phosphorus	PN	µg g^{-1}
	Particulate nitrogen	PP	µg g^{-1}
	Total Kjeldhal nitrogen (9)	Nk	mg N l^{-1}
	Calculated particulate org. C (11)	*POC cal	µg g^{-1}
Major ions (Annex XII)	Calcium	Ca^{2+}	mg l^{-1}
	Magnesium	Mg^{2+}	mg l^{-1}
	Sodium	Na^+	mg l^{-1}
	Potassium	K^+	mg l^{-1}
	Chloride	Cl^-	mg l^{-1}
	Sulphate	$SO_4^=$	mg l^{-1}
	Bicarbonate (12)	HCO_3^-	mg l^{-1}
	Sum of cations (13) (*)	TZ^+	µeq l^{-1}
	Sum of anions (14) (*)	TZ^-	µeq l^{-1}

(1) *Q*/*A*, (2) (*Q* × TDS)/1000, (3) (*Msnat* × 1000)/*Q*, (4) Sum of SiO_2 + Ca^{2+} + Mg^{2+} + Na^+ + K^+ + Cl^- + $SO_4^=$ + HCO_3^- expressed in mg l^{-1}, (5) HCO_3^- × 12/61, (6) TDC = average DOC + average DIC, (7) (POC × *Ms*)/*Q* or given in references, (8) *TOC = average DOC + average POC, (9) direct measurement on unfiltered sample, (10) Nk + $N\text{-}NO_3^-$ or given in references, (11) (TOC-DOC) loads divided by *Ms*, (12) in the great majority of rivers, pH is between 6 and 8.2 and bicarbonate ion is dominating, (13) Ca^{2+} + Mg^{2+} + Na^+ + K^+ expressed in µeq l^{-1}, (14) Cl^- + $SO_4^=$ + HCO_3^- + NO_3^- expressed in µeq l^{-1}, (15) (POC (mg l^{-1}) × 10^6)/TSS or given in references.

Annexes and tables refer to original report.

* Shows calculated values.

(iii) Annual water discharge >10 km^3 year^{-1} (or 317 m^3 s^{-1}) — in very humid regions (e.g. Papua New Guinea, Guyana, Indonesia), rivers smaller than 10 000 km^2 may be included.
(iv) Suspended load >5 Mt year^{-1} — highly turbid rivers smaller than 10 000 km^2 may be included as in Peru, Taiwan, New Zealand, California. They correspond to an average specific transport exceeding 500 t km^{-2} year^{-1} (2.5 times the world average).
(v) Very polluted basins — basins smaller than 10 000 km^2 with major industrial activities or with a very high population may be included such as the Thames, Escaut or Scheldt, Ems, etc. A population density exceeding 500 inhabitants per km^2 is used here as a first criterion (or 5 M people over 10 000 km^2), although this information is rarely available.

Spelling, homonyms and name confusions

Spelling is a major problem encountered in compiling a register of river discharges. Many rivers have at least two spellings, a Latin and an Anglo-Saxon transcription of the local name (e.g. Cuanza and Kwanza) in addition to a local transcription which may even change with time, as in the former Soviet Union, Burma or China. Two specific tables of river synonyms are given in the register. The worst problem is the transcription of Chinese names. The Yellow River is known either as Huang He, Huang Ho, Huang, and Hwang Ho; the Pearl River as Zhu Jiang, Xi Jiang, Chu Jiang, while the Red River in northern Vietnam is known as the Hong, Hung He and even the Song Koi.

In addition to the problems of name transcriptions into the Latin alphabet, there are confusions arising on many occasions from identical or very similar spellings. Sometimes they may even be located in the same country, as in the case of the Churchill rivers in Canada and the Fitzroy rivers in Australia. Some names, such as Colorado river (coloured river) or Rio Salado (salted river), are common throughout the world. These homonyms are also listed in a specific table in the register.

River identification

Identification is another type of problem occurring in rivers with double basins meeting in a single river mouth or estuary. Depending on the available water quality data, these rivers have been either separated (Usumacintas and Grijalvas; Thelon, Kazan and Quoich; Karun and Shatt el Arab) or aggregated (Koksoak, Mobile).

Based upon these criteria, 555 rivers have been accepted in the first version of GEMS-GLORI.

THE GEMS-GLORI DATABASE

The first phase of GEMS-GLORI is divided into five sets of data (Table 1) each corresponding to a different annex. The database has been structured to permit the following outputs: (i) rivers entering a given ocean or regional sea, (ii) rivers flowing from a continent or a country, (iii) rivers listed by latitudes (to check possible climatic effects), (iv) rivers listed by average runoff (to check possible difference between humid and arid regions), (v) rivers listed by Total Dissolved Solids (to check the influence of salinity, i.e. rock solubility and/or climate), and (vi) rivers listed by Total Suspended Solids (to check the influence of relief, rock erodability, etc.).

River location

Each river is attributed to: (i) the country of the river mouth, (ii) one of the six continents (Africa, North and South America, Asia, Europe, and Oceania or Australasia) and (iii) an ocean basin (Arctic and North Atlantic, South Africa, Indian, Pacific oceans) or five regional seas (Baltic, Hudson Bay, Black, Mediterranean, Persian Gulf).

The Arctic Ocean basin in Europe is limited by the 63°N latitude and includes all rivers discharging north between Norway and New Zemblia. The North and South Atlantic Oceans are limited by the equator. The mouth of the Amazon is just at this latitude but, since most of the flow of the biggest world river is diverted to the North by the Guyane current, the whole Amazon basin is considered here as a North Atlantic tributary. However, the Tocantins is allocated to the South Atlantic Ocean. The Pacific Ocean includes the South China Sea, Sulu Sea, Banda Sea and Java Sea. It is limited by the Malacca Straits. The Arafura Sea is part of the Indian Ocean, including the Gulf of Carpentaria. The southwest limit of the Pacific is Tasmania.

The eastern limits of Europe are the Ural continental divide and the northern side of the Caucasus (the Rioni and the Coroch rivers in Georgia are, therefore, considered as being in Asia). Oceania or Australasia includes the whole island of New Guinea (both Irian Jaya and Papua New Guinea), Australia, and all South Pacific Islands. The North American continent is defined as including Central America (as far as Panama) and all the Carribean islands. It must be noted that endorheic basins, particularly the Caspian basin and Central Asia, are not included in the first phase of GEMS-GLORI.

The coordinates (latitudes and longitudes) of the river mouth are essential descriptors which must be known in order to avoid the confusions mentioned previously. An attempt was made as far as possible to give these coordinates for every river listed. At present *c.* 530 rivers have coordinates for the river mouths, but a few small basins (of less than 10 000 km^2) are still missing.

Data selection

In many cases, multiple values can be found for the same river. This can occur for a variety of reasons including differences in analytical or sampling operations, differences in station location, different seasonal surveys (focus on droughts *vs.* focus on flood stage) and different survey periods due either to hydrological variations or to real trends in water quality caused by human impacts. This last point is particularly critical for the suspended load before and after dams. Therefore, in the first stage of GEMS-GLORI the natural suspended load (*Msnat*) prior to major human activities has been given as well as the actual load (Msact) derived from the most recent surveys.

For rivers having a very extended estuarine zone, the inclusion or exclusion of tributaries directly reaching the river may lead to a major discrepancy in basin area. The Saint Lawrence is a good example. In this report, the Saguenay is considered as a specific river and the Saint Maurice as a tributary of the Saint Lawrence basin which is defined in this database as ending at Québec city.

Whenever possible, several sets of data have been given with relevant references. The data selected for the first line in each record were the most reliable and generally were obtained first hand by local engineers or scientists and were associated with a time period for the record. Other data sources which the interested reader could go to for further information are also provided. Each record consists of three lines: selected data (in bold), reference (in italic), and period of record (plain text) (Table 2). Each reference starts with a two digit number indicating the publication year as 79.101 so that the number gives directly the period of publication and, therefore, an indication of the age of the record.

Calculated data

Data derived through calculation may also be found. This applies particularly to TSS which is obtained by dividing the annual natural suspended load (*Msnat*), that is

Table 2 Excerpt from GEMS-GLORI register for dissolved nutrients data.

Rivers	SiO_2 (mg l^{-1})	N-NO_3 (mg N l^{-1})	N-NH_4 (mg N l^{-1})	P-PO_4 (mg P l^{-1})	DOP (mg P l^{-1})	DON (mg N l^{-1})	DOC (mg C l^{-1})	*DIC (mg C l^{-1})	*TDC (mg C l^{-1})
Altamaha	**11.5**	**0.210**					**8.7**	**5.2**	**13.91**
	77.068	*77.068*					*91.097*		
	75	75							
Amazon	**6.9**	**0.14**	**0.020**	**0.022**	**0.015**	**0.162**	**4.1**	**4.1**	**8.23**
	92.035	*95.016*	*95.016*	*95.016*	*95.016*	*95.016*	*95.016*		
	11.2	**0.17**		**0.025**			**3.6**		
	79.101	*92.035*		*92.035*			*91.092*		
		88.173		**0.023**			**3.3**		
				88.173			*91.096*		
Ameca	**30.1**							**17.7**	
	71.022								
Amgerman								**9.4**	
Amguema	**5.9**	**0.025**		**0.012**				**1.5**	
	95.006	95.006		95.006					
Amur	**2.15**	**0.02**	**0.43**	**0.021**				**5.7**	
	96.004	*96.004*	*96.004*	*96.004*					
	80-90	80-90	80-90	80-90					
	2.25	**0.04**	**0.36**	**0.35**					
	95.001	*95.001*	*95.001*	*85.186*					
	80-92	80-92	80-92						

Emboldened values (first line for each entry)show selected data, italicized values (second line for each entry) show corresponding reference number starting with reference year, values in plain text (third line for each entry) show time period of record, where appropriate.

* Shows calculated data.

generally based on specific surveys focusing on the flood stage, by the annual water discharge (*Q*) expressed in km^3 $year^{-1}$. The "average" TSS, as obtained from regular water quality surveys, has been dropped here for two reasons. Firstly, these surveys do not sample TSS adequately due to a lack of specific sampling apparatus, and a lack of sampling specific to the rising flood stage, etc. and secondly, the mean values are generally arithmetic and are not discharge-weighted. The Total Dissolved Solids (TDS), Dissolved Inorganic Carbon (DIC), Total Dissolved Carbon (TDC), which is the sum of DOC + DIC, were also calculated. As the Total Organic Carbon (TOC) is generally measured directly on unfiltered samples, it has been differentiated here from the calculated sum of DOC + POC.

The analysis of the particulate matter (POC, PP, PN) can be given either as the content of suspended matter ($\mu g\ g^{-1}$), or expressed as the concentration of a particulate element found in a volume of unfiltered matter ($mg\ l^{-1}$). Most authors prefer the first approach where the annual load of POC, PP and PN is then obtained by combining the annual suspended load with annual mean content. Yet in some cases PP, or POC, may still be reported in $mg\ l^{-1}$ and the loads are simply obtained as the product of average concentration and annual volume which can lead to underestimation. When the POC, PP or PN annual loads are the only available data, their average content in the suspended particles is calculated (e.g. POC content = POC load/TSS load).

Average values

Wherever possible, recent annual long-term averages have been used, i.e. including the various human impacts. However, these averages should not be based on too long a period in which a trend could have occurred in water quality descriptors. The optimum period of record required is probably five years for the dissolved contents and 10 years for the suspended load and analyses of suspended particulates. In reality, there is little choice of data in most cases because the period of record may be even less than one full hydrological cycle. In many cases, the exact dates for records are completely missing. This information is particularly important for the annual suspended load (Ms) which may commonly vary by one order of magnitude from year to year.

The present database of GEMS-GLORI; phase one, contains 10 000 individual data values.

REPRESENTATIVENESS OF GEMS-GLORI DATABASE

For this first report on the GEMS-GLORI database about 555 rivers have been selected of which 500 have a basin area exceeding 10 000 km^2.

Of the 555 rivers listed in the register, 468 have been documented for both drainage area (*A*) and water discharge (*Q*). The total area is 75.7 Mkm^2 and the total discharge is 26 775 km^3 $year^{-1}$ or 76% and 72% of the global figures, respectively, based on the world water balance of Baumgartner & Reichel (1975). Their balance, although not the most recent one, is still the most useful for global budgets since it gives complete breakdown of river inputs per continent, oceans and latitudinal zones. The average runoff in GLORI is 354 mm $year^{-1}$, i.e. only 5.5% less than the global average without Greenland and Antarctica (374 mm $year^{-1}$) calculated by Baumgartner & Reichel. When considering specific key water quality attributes, coverage varies from 44% to 67% (Table 3). Increasing these proportions by 10%

would need information on more than 100 to 200 additional rivers (Meybeck, 1988; Milliman & Syvitski; 1992).

The representativeness of a global river dataset must be checked on other criteria such as ocean drainage, continental drainage and latitudinal zone. If these criteria are satisfied, it is hoped that many others are satisfied as well (e.g. relief and tectonics; climate and vegetation; human impacts). An example of such a checking procedure can be provided here for the 180 GEMS-GLORI rivers where nitrate data are available. The volume of flow per continent (Table 4) for which NO_3^- has been documented appears to be representative in percentage terms of the continental contributions to global runoff in the case of North America, Asia, Europe and Africa. However, South America is clearly over-represented in the NO_3^- data because of the enormous weight of the Amazon, which accounts for *c*. 17.6% of world discharge, while Australasia is significantly under-represented due to the general lack of NO_3^- data from the very humid region of New Guinea.

The distribution by ocean basins of rivers for which NO_3^- data are available (Table 5) reveals an over-representation of the Arctic Ocean and Atlantic Ocean rivers, while Indian Oceans rivers are actually strongly under-represented because data are lacking for most India rivers and some East Africa ones, as well as rivers draining New Guinea. In consequence, the NO_3^--budget to the Indian Ocean cannot

Table 3 Global representativeness of GEMS-GLORI as indicated by the percentage of global exorheic area and discharge documented for various descriptors of water quality.

Descriptor	Percentage of area	Percentage of discharge	Total number of rivers
Major ions	67.0	63.0	250
$N\text{-}NO_3^-$	54.6	51.5	180
$N\text{-}NH_4^+$	51.4	50.7	113
$P\text{-}PO_4^{3-}$	43.9	44.6	130
SiO_2	64.0	60.0	200
DOC	44.0	44.5	56
POC	40.6	41.7	42
TSS	64.0	60.0	217

Global values of area (100 Mkm^2) and discharge (37 400 $km^3\ year^{-1}$) are taken from Baumgartner & Reichel (1975).

Table 4 The continental distribution of runoff to the oceans and corresponding drainage area for the globe and for rivers in GEMS-GLORI which have been documented for NO_3^-.

	Global[1]			Documented		
	ΣA	ΣQ	*qexor*	ΣA	ΣQ	*qexor*
Africa	17.56	3 409	194	6.64	1 394	210
N. America[2]	21.60	5 540	256	12.80	2 927	229
S. America	16.40	11 039	672	11.35	9 129	804
Asia	31.45	12 467	396	17.70	4 518	255
Europe	8.27	2 564	310	4.92	1 233	251
Australasia	4.70	2 394	509	1.11	124	112
Global total	100.00	37 400	374	54.50	19 323	354

ΣA = sum of drainage area (Mkm^2), ΣQ = sum of water discharge ($km^3\ year^{-1}$), *qexor* = runoff for the exorheic part of the continents (mm $year^{-1}$).

[1] According to Baumgartner & Reichel (1975),

[2] Without Greenland.

Table 5 The distribution by ocean basins of runoff to the oceans and corresponding drainage area for the globe and for rivers in GEMS-GLORI which have been documented for NO_3^-.

	Global[1]			Documented		
	ΣA[1]	ΣQ[2]	*qexor*	ΣA	ΣQ	$\%Q$
Arctic	22.4	1 611	116	2 157	204	82.6
Atlantic	43.1	19 051	442	13 537	314	71.0
Indian	14.7	5 601	381	474	11	8.5
Pacific	19.8	10 137	512	3 155	351	31.1
Global total	100.00	37 400	374	54.50	19 323	51.7

ΣA, ΣQ and *qexor* are as described in Table 4, $\%Q$ = documented sum of water discharge as a percentage of the global sum of water discharge.

[1] Adapted from Korzun (1978).

[2] After Baumgartner & Reichel (1975).

be based on GEMS-GLORI at its present stage.

The latitudinal distribution of river mouths is another way to check the representativeness of the database. In terms of NO_3^- data, the Arctic regions (90°N to 55°N) are slightly over-represented (Table 6) since most Siberian and Canadian rivers are well surveyed, while the southern temperate latitudes (35°S to 55°S) are very poorly documented in GEMS-GLORI. However these regions account for only 3.8% of the global river discharge to oceans. This is mainly derived from Patagonia which is represented in the register only by the Bio-Bio River.

CONCLUSIONS AND FUTURE DEVELOPMENTS

Although not the first global river register, GEMS-GLORI is the most complete and updated one devoted to river chemistry. Its representativeness is between 40% and 67% for most common water quality variables (PO_4^{3-}, NO_3^-, DOC, major ions, TSS) when drainage area or river discharge is considered, but drops to less than 30% for particulate P and N. All continents and oceans basins are well covered but a general lack of data is still noted for some regions (New Guinea, Patagonia, India for nutrients) while some others (Arctic Ocean rivers, South America rivers) are much

Table 6 The distribution by latitude of river mouth basins of runoff to the oceans for the globe and for rivers in GEMS-GLORI which have been documented for NO_3^-.

Latitudes	Global	Documented	
	ΣQ[1]	ΣQ	$\%Q$
55°N-90°N	5 313[2]	3 362	63.4
35°N-55°N	4 585	2 511	54.8
15°N-35°N	6 404	2 512	39.2
15°S-15°N	8 047	10 010	55.5
15°S-35°S	1 652	864	52.3
35°S-55°S	1 408	65	4.6
Global	37 400	19 324	51.7

ΣQ and $\%Q$ as described in Tables 4 and 5.

[1] After Baumgartner & Reichel (1975).

[2] Without Greenland.

better documented than average. However, it is believed that GEMS-GLORI can be used to compute world budgets at global scale and, in most cases, some regional ones provided that sound procedures are used (Meybeck, 1988).

These data, which are now circulated for comment and additions, should be carefully scrutinized by the scientific and engineering communities. Despite the efforts of the authors, there are still numerous errors, misspellings or missing key references, and it is acknowledged that this first register is not yet comprehensive, particularly for the smallest basins (<50 000 km^2). Therefore, any comments, corrections and additions are most welcome and should be addressed to the first author of this report. These changes will be taken into account in the next phase of this register.

The GEMS-GLORI register at this stage is mainly focused on present-day data which combine rivers still in a pristine state (Amazon, Orinoco, Zaire, Lena, Mackenzie), rivers being impacted by human activities (Saint Lawrence, Ob), and rivers already affected at various stages of impacts, such as nutrient pollution (Rhine, Seine), damming (Colorado, Nile, Indus), salt pollution (Rhine, Vistula), land management (Huang He, Chang Jiang), etc.

Some of the possible future developments of GEMS-GLORI are the following:

(i) Completing information on the land/ocean global geochemical cycling with data on particulate forms of the major elements (Ca, Mg, Na, K, Cl, S and Al, Fe, Mn, Ti).

(ii) Assessing long-term trends of water quality. In a few rivers the major ions have been analysed for over a hundred years. It is believed that such a database could be extremely useful for assessments of local-and regional-scale water quality issues and as a basis for calibration/validation of global scale typologies and modelling.

(iii) Adding information on the potentially harmful inorganic substances. This concerns many inorganic substances (As, Cd, Cu, Hg, Ni, Pb, Se, Sb, Zn) and other microelements.

(iv) Completing the dataset by adding information on the few major rivers that are still poorly documented. Some data from tributaries could also be stored in the database if they are particularly well documented and homogeneous.

(v) Completing the database with information on large rivers discharging to inland water bodies as the Volga, Amu Darya, Syr Darya, Chari, Desaguadero, Okawango, etc.

It is hoped that, in the future, GEMS-GLORI will be one key component of the River Archives Series which is a set of global geo-referenced and computerized data on surface waters (quantity, quality, uses) as proposed to the first IGBP congress in 1996, at Bad Munster Eifel by C. Vörösmarty and M. Meybeck to BAHC, PAGES and LOICZ.

Acknowledgements Dozens of scientists have exchanged data with the authors since the 1970s. They are all warmly acknowledged, particularly those involved in the SCOPE-Carbon programme led by the late Egon Degens. We have also extensively used the data from Russian colleagues, such as V. Georgievsky, V. Gordeev and V. Tsirkunov, who have contributed to the Assessment of Water Quality Issues in the Former Soviet Union (in press). GEMS/Water Data were kindly provided by A. Fraser (National Water Research Institute, Burlington, Ontario, Canada). GEMS-GLORI is an activity of the GEMS/Water Programme funded by UNEP and coordinated by R. Helmer (WHO, Geneva) whose support and interest is warmly appreciated.

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