Environment Information and Assessment

River Discharges to the Oceans: An assessment of suspended solids, major ions and nutrients

Prepared by
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1. Background

Freshwater of acceptable quality, is a critical imperative for sustainable development. Water quality is also an integrated indicator of global environmental change and of local and regional environmental pollution impacts. Thus the world's water resources require effective monitoring and assessment programmes that cover entire watersheds and are global in scope. The Global Water Quality Monitoring Programme, 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. To respond to emerging global priorities for water quality and to provide the required information, major emphasis is placed, during phase two of the GEMS/WATER programme (1990 to 2000), on comprehensive data collection, interpretation and assessment of regional and global water quality issues and on the resulting needs for pollution control.

Recognizing the large quantity of pollutants carried from land by rivers, the GEMS/WATER programme adopted, as one of its three objectives "to provide to goverments, to the scientific community and to the public, information on the transport and, if necessary, assessments of the fluxes of toxic chemicals, nutrients and other pollutants from major river basins to the continents/ocean interface." The assessment of pollutant fluxes by rivers contributes, therefore, directly to UNEP's efforts towards the development of a programme of action for the protection of the marine environment from land-based activities. The related Global Programme of Action stipulates the establishment of linkages with the activities of ongoing international programmes monitoring and assessing the state of the marine environment and relevant river systems, such as the GEMS/WATER programme.

Early attempts to collect and to systematize published documentation on river fluxes were undertaken by UNESCO, including a World Register of River Inputs (WORRI), as a contribution to the UNEP Regional Seas programme and a GESAMP report (87.193). A first series of river catalogues was prepared for the Mediterranean, the Gulf of Guinea, the Caribbean, and the South-East Asian Seas. The first named author of the present report was responsible for these documents which were, however, never formally published.

Considering the growing demand for riverine data, and for data which are available through programmes such as GEMS/WATER and through the completed SCOPE/CARBON programme, IGBP/LOICZ launched in May 1994 (after an expert meeting in Strasbourg headed by J.D. Milliman), a new global register named GLORI (Global River Index). This register lists about a thousand rivers with their basic river basin characteristics, total suspended solids and total dissolved solids. The report was issued by LOICZ in April 1995 (Milliman, J.D., Rutkowski, C., and Meybeck, M., 1995) (95.013).

In parallel, as agreed between IGBP/LOICZ and GEMS/WATER, another register was established on somewhat expanded grounds by the authors of the present report. This register, know 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. It represents the results of the personal experience of the two authors accumulated over 20 years, combined with the ongoing GEMS/WATER monitoring data collection, and with an extensive literature search in scientific journals and reports.

A GEMS/WATER Expert Consultation on the Assessment of Land-Based Sources of Pollution was convened in Koblenz in June 1995 specifically to discuss methods and data needs for quantifying and predicting flux and transport of relevant pollutants from the perspective of regional and global assessment. The IGBP/LOICZ report on GLORI and the draft of the present GEMS/GLORI report were reviewed by the group and recommendations as to their merging, expansion and continuation within a comprehensive data bank were made.

2. The GEMS/GLORI activity

The objectives of GEMS/WATER require assessments of the fluxes of toxic chemicals, nutrients and other pollutants from major river basins to the continent/ocean interface. Taking into account similar needs of IGBP/LOICZ, a general framework was developed within which the two organizations developed their data collection systems. The GEMS/GLORI component was set up in accordance with the objectives and scope described below.

2.1 Objectives

The objectives for a first phase, which concludes with the present report, were:

(1) To collect water quality data on major world rivers discharging to the oceans (i.e. exorheic), near the river mouth and upstream of any ocean influence, i.e. saline intrusion or dynamic tide.

(2) To collect data which represent recent interannual averages, i.e. at least 5-year averages, if possible, for dissolved concentrations, and at least 10-year averages for total suspended substances.

(3) To collect data which represent actual water quality as influenced by anthropogenic activities such as pollution, mining, damming, etc.

(4) To accept only data which are associated with bibliographic references or personal communications and indicate a time period for the measurements.

(5) To collect data on the following characteristics:
- general features of the river basin
- total suspended solids (TSS) and total dissolved solids (TDS)
- C, N, P, Si (dissolved species)
- C, N, P (particulate species), and
- major ions in dissolved form, including Ca, Mg, Na, K, Cl, S.

In the next phase the intention is to expand the data base towards the major ions in particulate form, minor and trace elements, as well as organic micropollutants both in dissolved and particulate form. Major rivers discharging to internal areas of continents (i.e. Endorheic), such as the Volga, could also be incuded.

2.2 *River selection criteria*

In order to keep within a manageable size for the data base but still to cover all major rivers, it was agreed to adhere to the following four criteria for including a river in GEMS/GLORI:
(1) Exorheic river basins exceeding 10,000 km^2, or
(2) Basins exceeding a water discharge of 10 km^3/a (ca. 300 m^3/s), or
(3) Rivers exceeding a sediment discharge of 5 Mt/a, or
(4) Basins with a population exceeding 5 million inhabitants.
The last criterion was more difficult to apply.

2.3 *Selection of parameters*

The data base was developed with entries for the following information (number of parameters in parenthesis):
- Detailed river description (9)
- General hydrological features and total loads (9)
- Dissolved nutrients (10)
- Particulate nutrients (11)
- Major ions (9)

A detailed structure of the data is provided below in section 5.1.

3. Data sources

All relevant data sources have been identified and listed with a five digit code starting with the year of publication. Both alphabetical and chronological lists of references are given in Annexes XII and XIII.

3.1 *General sources of data*

Relevant data sources were examined between November 1994 and June 1995 as follows:

(1) Countries official yearbooks (water discharge and water quality) or state of the environment reports (e.g. 78.166).

(2) UN agencies reports e.g.:
- Unesco River Discharges published in the 1960s and early 1970s (71.097).
- UNEP/UNESCO Regional Seas Reports on the Mediterranean, Gulf of Guinea (81.185), Caribean and Gulf of Mexico, South East Asia seas (80.150).
- River discharges by the Global Run-off Data Center, Koblenz, Germany.
- Former WORRI register (UNEP/UNESCO) (78.161; 79.179).

(3) Specific books on global hydrology e.g.:
- World Water Balance and Water Resources of the World (Soviet IHD Committe, UNESCO) 1978 (78.090).
- Van der Leeden et al. 1975. Water Resources of the World (75.109).
- From Dniepr to Baikal, Water Quality Issues in Former Soviet Union (GEMS/Water, in progress).
- Degens, Kempe, Richey, 1990 Biogeochemistry of Major World Rivers (90.165).

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

(5) Scientific literature found in books and symposia. These following journals were systematically investigated during the five years: Limnology & Oceanography, Hydrobiologia; Water Research; Hydrological Sciences Journal; Journal of Hydrology; Marine Chemistry; Orstom publications; Verhandlungen Internationale Vereinigungs. Limnologie.

(6) Previous reviews (on a global scale or on a regional scale) were also considered: (Durum, Heidel and Tison 1960 (60.018); (Livingstone 1963 (63.024); Milliman & Meade 1983 (83.055); Milliman & Syvitski 1992 (92.009); Gordeev (95.001); Meybeck 1979 (79.101), 1982 (82.096); Curtiss, Culberson & Chase 1973 (73.040); Stickling 1974 (74.015) Considering the size of the former Soviet Union special attention was paid to these rivers and to the reviews of Georgievski et al. (1996), V. Tsirkunov et al. 1996 (96.004), and V. Gordeev and V. Tsirkunov 1996 (96.003), which were given priority. These review were based on numerous references such as 48.004, 50.002, 51.005, 60.022, 64.041, 75.112, 78.108, 78.168, 78.169, 83.245, 83.246, 85.203, 86.223, 87.194, 88.226, 88. 227, 91.083, 91.084, 93.030, 93.031, 95.006 which are listed in Annex XIV.

A very important source is the Mitteilungen of the Geological and Palaeontological Institut of Hamburg University (82.093, 83.017, etc.) which hosted and published the results of the UNEP programme called SCOPE Carbon which lasted more than 10 years under the direction of the late Egon Degens. This programme was devoted to the world's biggest rivers in every continent, initially for carbon species only and then for major ions, nutrients and even some metals. An important synthesis of this programme has been published in the SCOPE series by Degens, Kempe & Richey (1991). Another set of studies on the Zaire, Niger and Amazon rivers has been published by Olivry and Boulegue (95.007).

Altogether about 500 different sources have been considered and reported here. The ultimate aim of GEMS/GLORI is to associate any river water quality data set with the relevant references and period of survey.

It must be noted that most of this literature search was carried out during the last 15 years since the launch of the first global register on river quality (WORRI and Regional Seas Programme).

3.2 *Specific sources of data*

River discharges and basin area: At the global scale the major references are UNESCO reports on River Discharge of the World (69.065; 71.097), Global Run-off Data Center reports in Koblenz (Germany), UNEP/UNESCO WORRI and Regional Seas Reports, Soviet works (World Water Balance and Water Resources of the World, 1978 (78.090)) ORSTOM reports for Africa and some South American countries (Office de la Recherche Scientifique et Technique d'Outre Mer, Paris), Van der Leeden publication (75.109) and the Milliman & Syvitski review (1992). At the national scale the local reports from Environment Canada as on the Mackenzie basin (85.204), U.S. Geological Survey, Indian publications such as from Rao (79.181), Subramanian and Indian Committee of the Int. Hydrol. Decade, and Soviet publications by Georgievski et al. (96.005) were used. Since many rivers are now exposed to damming, irrigation or diversion, their water discharge is no longer natural (94.034). The natural discharges have been mentioned in a separate data column from the actual discharge (i.e. modified). When the status of the discharge data was unknown they were referred to as an "actual discharge".

River length, basin average rainfall: These data are mostly derived from Van der Leeden and from the Soviet works mentioned above.

Suspended load: This data came mostly from the Milliman & Syvitski (1992) review. 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. (96.005) and Gordeev and Tsirkunov (96.003) were preferred. Former reviews by UNESCO and IAHS were also used (74.041).

Major Ions and Total Dissolved Solids (TDS): Total dissolved solids are calculated as the sum of major ions (Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-}, $SO_4^{=}$, HCO_3^{-}) plus dissolved silica, when available, (expressed as SiO_2). The TDS is an indication of the level of water mineralization. These data, as well as the Dissolved Inorganic Carbon (DIC, essentially present in river waters as HCO_3^{-}), come from very diverse sources collected by many scientists, e.g. Livingstone (1963), Kobayashi (1959, 1960), Briggs & Ficke (1977), Meybeck (1979), Tsirkunov (96.002), Probst (1992) and from dozens of specific scientific publications. Country reports were also collected and used (i.e. Canada, France, Germany, Finland, Spain, Turkey, Soviet Union).

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, which have been preferred here to arithmetic means (the water discharge weighted averages are not yet available).

In addition to the SCOPE CARBON publications (82.093; 83.017; 90.165), most carbon and nutrients analyses which are rarely performed in regular surveys, such as particulate nitrogen, particulate phosphous and even dissolved organic carbon, have been found in specific publications such as Lewis & Saunders (1989) for the Orinoco, Richey et al. (1990) for the Amazon, Lesack et al. for the Gambia (84.072), Cauwet & Mackenzie (93.024) for the Huang He, and Mulholland & Watts (1982) for the North American rivers, etc.

The alphabetical lists of basic sources of information on world river quality (general characteristics, suspended load, TDS, major ions, nutrients and organic carbon) is given at the end of this report (Annex XIII). Each reference has been numbered according to the publication year, for example reference 85.109 is the number 109 entered in the reference data base. These numbers are used to indicate the origin of the data for each river listed in GEMS/GLORI. The chronological list of reference is presented in Annex XIV.

4. Selection of rivers

4.1 *Criteria for inclusion*

The following criteria were retained within this first phase.

(1) *Rivers discharging to oceans.* No rivers discharging to internal regions are included in this first phase (e.g. Volga, Chari, Amu Darya).

(2) *Drainage area > 10 000 km²*. In some regions the drainage area can be very loosely defined. As a result, only the biggest basins are included in semi-arid regions where run-off is less than 1 L/s/km² or 30 mm/a as in Somalia, NE and E Australia. Therefore many relatively small river basins (10 000 to 50 000 km²) that are not permanent (e.g. oueds, wadis, aroyos, etc.) may be missing here (e.g. Peru, South Argentina, Namibia,

Somalia, Eastern and North-Eastern Australia, etc). When the average run-off is less than 0.1 L/s/km^2 (3 mm/a) the surface run-off is not organized and drainage area data are generally absent. Such basins are considered as arheic. These regions are generally aggregated by geographers (such as the Soviet geographers) with the truly endorheic basins (e.g. Mauritania, parts of Arabia, etc).

(3) *Annual water discharge > 10 km^3/a* (or 317 m^3/s). In very humid regions rivers smaller than 10 000 km^2 may be included (e.g. Papua New Guinea, Guyana, Indonesia) when their specific run-off exceeds 1 000 mm/a, or about 2.7 times the world average.

(4) *Suspended load > 5 million t/a (Mt/a).* 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 of 500 t/km^2/a (2.5 times the world average).

(5) *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 Thames, Escaut, Ems, etc. This criterion is, as yet, mainly subjective and will have to be more clearly defined on the basis of the population within the basin and its type of economy with respect to the potential pollution. A population density exceeding 500 inhabitant/km^2 is used here as a first criterion (or 5 M people over 10 000 km^2), although this information is rarely available.

Some karstic rivers may have an underground basin much greater than the topographic one. This is the case for the Manavgat river (Turkey) which is selected here.

Based upon these criteria, 545 rivers have been accepted here in the GEMS/GLORI register. They are listed in Table I by alphabetical order. The spelling of their names is discussed in the following section.

4.2 *Spelling difficulties, river identification, and homonyms*

Spelling

Spelling is not the only problem encountered in such a register. 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 Burma or China. The biggest rivers that flow through numerous countries have three or for different spellings (Rhin, Rhine, Rhein, Rijn; Danube, Donau Dunai; Maritsa, Meric, Evros; Ganges, Ganga, Padma; Brahmaputra, Jamuna; Paatsjoki, Patsjoki, Pasvikelva, Pateo Joka, etc.).

Recent transcriptions of original names have also changed in the countries themselves: for example the Myanmar, formerly Burma, now names the Irrawaddy "Ayerarwady", and the Salween, Thanlwin. Double official spelling can sometimes be found for the same river as in India, Narmada and Narbada, or in Thailand, Chao Phrya and Chao Phraya!

Table I Alphabetical list of GEMS/GLORI rivers

A LA BALEINE	BROADBACK	DELAWARE	GOURITS	KANIRIKTOV
ABITIBI	BUG	DESEADO	GR BALEINE	KAOPING
ABRA	BULLER	DIGUL	GRANDE	KAPUAS
ADIGE	BURDEKIN	DNEPR	GRANDE DE SANTIAGO	KARUN
ADOUR	BURNETT	DNESTR	GRANDE MATAGALPA	KAZAN
AGANO	BUYUK MENDERES	DOCE	GREAT FISH	KELANTAN
AGNO	BUZI	DON	GREAT KEI	KEM
AGUSAN	BZYB	DONG NAI	GREY	KEMIJOKI
AKSU		DONGJIANG	GRIJALVA	KENNEBEC
ALAZEYA	CAGAYAN	DORDOGNE	GUADALUPE	KHATANGA
ALBANY	CAPE FEAR	DOURO	GUADIANA	KIKORI
ALIAKMON	CAPIM	DRAA	GUALDALQUIVIR	KISO
ALSEK	CAUWERI	DRAMMENSELVA	GUAYAS	KITAKAMI
ALTAMAHA	CAVALLY	DRINI	GUNDLAKAMMA	KIZIL IRMAK
AMAZON	CEYHAN		GURUPI	KLAMATH
AMECA	CHANG JIANG	EASTMAIN		KOBUK
AMGERMAN	CHAO PHRYA	EBRO	HAAST	KODORI
AMGUEMA	CHELIFF	EEL	HAI HO	KOKEMAENJO
AMUR	CHICO	ELBE	HAN	KOKSOAK
ANABAR	CHIRA	ELLICE	HANJIANG	KOLA
ANADYR	CHO SHUI CHI	EMS	HARI	KOLYMA
ANDERSON	CHOCTAWATCHEE	ERHIAN	HARRICANA	KONKOURE
ANGHARI	CHOWAN	ESCAMBIA	HAYES	KOUILOU
ANKOBRA	CHUBUT	ESCONDIDO	HELLEH	KOVDA
APPALACHICOLA	CHURCHILL (Atl)	ESMERALDAS	HOKITIKA	KRISHNA
APPROUAGUE	CHURCHILL (Hud)	ESSEQUIBO	HONG	KUBAN
ARAGUARI	CIMANUK	EVROS	HSIUKULUAN	KUSKOKWIM
ARNAUD	CITANDUY		HUAI	KVICHAK
ARNO	CITARUM	FILYOS	HUALIEN	KYMIJOKI
ASHBURTON	CLARENCE	FITZROY EAST	HUANG HE	
ASI	CLUTHA	FITZROY WEST	HUDSON	LA GRANDE
ATRATO	COCO	FLINDERS	HUN	LANYANG
ATTAWAPISKAT	COLORADO (Arg)	FLY	HUNTER	LEICHHARDT
AURE	COLORADO (Ari)	FORSTESCUE		LEMPA
AUX FEUILLES	COLORADO (Tex)	FRASER	IKOPA	LEMRO
AUX OUTARDES	COLUMBIA	FUCHUN JIANG	INCOMATI	LENA
AXIOS	COLVILLE	FUERTE	INDALSALVEN	LIAO
	COMOE	FYRIS	INDERAGIRI	LICUNGO
BABBAGE	CONNECTICUT		INDIGIRKA	LIELUPE
BACK	COPPENAME	GALANA	INDUS	LIGONHA
BAKER	COPPER	GAMBIA	INGURI	LIJOKI
BALSAS	COPPERMINE	GAMTOOS	IRRAWADDY	LIMPOPO
BAN PAKONG	CORANTIJN	GANGES	ISHIKARI	LJUNGAN
BANDAMA	COROCH	GARONNE	ISSER	LLOBREGAT
BARITO	CROSS	GASGOYNE	ITATA	LOIRE
BARUMUM	CUANZA	GAUJA		LUAN
BERBICE	CUNENE	GEDIZ	JACUI	LUGA
BERSIMIS	CUYUNI	GEORGE	JAMES	LULEALVEN
BETSIAMITES		GILBERT	JEQUITINHONHA	LURIO
BETSIBOKA	DALALVEN	GIZHIGA	JIULONG	
BIO BIO	DALING	GLAMA	JUBBA	MACKENZIE
BRAHMANI	DALY	GLENELG	JUCAR	MAE KLONG
BRAHMAPUTRA	DAMODAR	GODAVARI		MAGDALENA
BRANTAS	DANUBE	GOKSU	KALADAN	MAHAKAM
BRAZOS (Tex)	DAUGAVA	GORONGOSE	KALIX	MAHANADI
BREEDE	DAULE	GOTA	KAMCHATKA	MAHI

Table I Alphabetical list of GEMS/GLORI rivers

MAIPO	NEVA	PIURA	SAVE	TEVERE
MAJES	NICKERIE	PO	SAVIO	THAANNE
MAMBERAMO	NIGER	PONNAIYAR	SCHELDT	THAMES
MANA	NILE	PONOI	SEAL	THELON
MANANARA SUD	NIVA	POTOMAC	SEBOU	THJORSA
MANAVGAT	NOATAK	POVUNTNITUK	SEGURA	TOCANTINS
MAND	NOTTAWAY	PRA	SEINE	TOKACHI
MANDRARE	NTEM	PREGOLYA	SEMANI	TONE
MANGOKY	NUECES	PROGO	SENEGAL	TORNIONJOKI
MANICOUAGAN	NUSHAGAK	PULANGUI	SEPIK	TRENT
MAPUTO	NYANGA	PUNGOE	SERAYU	TRINITY
MARKHAM	NYONG	PUR	SEVERN (Can)	TSENGWEN
MARONI	NZI	PURARI	SEVERN (GB)	TSIRIBIHINA
MAULE		PYASINA	SEYBOUSSE	TUGUR
MAZARUNI	OB		SEYHAN	TULOMA
MEARIM	ODRA	QUOICH	SHANNON	TURIA
MEDJERDA	OGOOUE		SHATT EL ARAB	
MEGHNA	OLENEK	RAJANG	SHCHUCHYA	UDA
MEKONG	OLFUSA	RAMU	SHINANO	ULUA
MENJIANG	OLIFANTS	RAPEL	SHKUMBINI	UME-VINDEALVEN
MERRIMACK	OMOLOY	RED	SIMAV	UMPQUA
MESSALO	ONEGA	RESCATA	SINNAMARY	URUGUAY
MEUSE	ONILAHY	RHINE	SITTANG	USUMACINTA
MEZEN	ORANGE	RHONE	SKAGIT	
MINDANAO	ORD	RIO GRANDE (US)	SKEENA	VAMSADHARA
MINHO	ORINOCO	RIONI	SKELLEFTALV	VAR
MIRA	OUEME	ROANOKE	SKIENSELVA	VELLAR
MISSISSIPPI	OULUJOKI	ROGUE	SNOWY	VENTA
MITCHELL	OUM ER RBIA	ROMAINE	SOFIA	VICTORIA
MOA	OYAPOK	ROPER	SOLO	VIJOSE
MOBILE		RUFIJI	SOUMMAM	VOLTA
MOGAMI	PAHANG	RUPERT	SOUS	VORONYA
MOISIE	PALAR	RUVUMA	STIKINE	
MONO	PAMPANGA		STRYMON	WAIAU
MOOSE	PANGANI	SABARMATI	SUBARNAREKHA	WAIKATO
MOTAGUA	PANUCO	SABINE	SURINAME	WAIMAKARIRI
MOULOUYA	PAPALOAPAN	SACRAMENTO	SUSITNA	WAIPAOA
MURCHISON	PARAIBA DO SUL	SAGUENAY	SUSQUEHANNA	WAITAKI
MURRAY	PARANA	SAINT AUGUSTIN	SUWANNEE	WAMI
MUSA	PARNAIBA	SAINT JOHN	SWAN-AVON	WESER
MUSI	PASAK	SAINT JOHN'S		WINISK
	PASCAGOULA	SAINT LAWRENCE	TA CHIA CHI	WISLA
N. DVINA	PATSJOKI	SAKARYA	TAKU	WOURI
NADYM	PATUCA	SALADO (Arg)	TAMBO	WU CHI
NAG DONG	PEARL	SALINAS	TAN SHUI	
NAGAVALI	PECHORA	SALWEEN	TANA (Ken)	YALU
NARMADA	PEE DEE	SAN ANTONIO	TANA (Nor)	YANA
NARVA	PEEL	SAN JOAQUIN	TANO	YENISEY
NASKAUPI	PEINAN	SAN JUAN	TAPTI	YESIL
NASS	PENNER	SANAGA	TAR	YODO
NATASHQUAN	PENOBSCOT	SANTA	TAUY	YUKON
NECHES	PENZHINA	SANTA CLARA	TAYMYRA	ZAIRE
NEGARA	PERAK	SANTA CRUZ	TAZ	
NEGRO (Arg)	PERIYAR	SANTEE	TEJO	ZAMBEZI
NELSON	PETIT MECATINA	SAO FRANCISCO	TENRYU	ZEROUD
NEMANUS	PETITE RIVIERE BALEINE	SARAMACCA	TENSIFT	ZHUJIANG
NERETVA	PINIOS	SASSANDRA	TERENGGANU	
NEUSE	PITALVEN	SAVANNAH	TESHIO	

A particular problem can occur with the transcription of a river name from arabic and cyrillic alphabets (as both the Penzhina and Penjina can be found on various atlases and maps). Another problem is the inclusion of adjectives in the name. The Northern Dvina is known in Russia as the Severnaia Dvina, and the outlet of lake Taymir is found either as Taymira or Nysh Taymira. The Orontes river, famous during antiquity, is now known as the Nahr El Asi or Asi. In Indonesia various spelling types are found such as Cimanuk, Tjimanuk and Manuk (Kummerly & Frey Atlas). A major Siberian river is either known as Kheta (National Geographic Society maps) Khatanga or Chatanga (Kummerly & Frey). These atlas and maps (references 89.176, 00.008 and 91.086) have been the basic tools in this report. The Physico-Geographic Atlases of the World published in Moscow (64.04) has also been of great help.

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 Viet Nam is known as the Hong, Hung He and even the Song Koi.

In most cases the following general rules were followed:
(a) the local name of the most downstream country is generally preferred, as for the Zaire,
(b) priority to the National Geographic Society (Washington DC) spelling as found in its maps or atlas.
© common English name is preferred (as for the Saint Lawrence, the Rhine or the Danube), and
(d) other atlases, such as the Kummerly & Frey and the Times Atlas (London), have also been used.

Sometimes the river name had to be abbreviated because it was too long for the listing, for example the Rio Grande de Santiago was entered as "Santiago" and the Rio Bravo del Norte (Mexican name) as the Rio Grande (USA name). In many countries the part of the name indicating that the toponym is a river was generally retained, as in the <u>Ci</u>manuk (Indonesia), the Dal<u>alven</u> (Sweden), the Huang <u>He</u> (China), the Kemi<u>joki</u> (Finland).

A comparative list of local or national synonyms together with spelling adopted in GEMS/GLORI is given in Tables II and III.

River identification
Another type of problem occurred with the rivers with double basins meeting in a single river mouth or estuary such as the Koksoak in Québec, sometimes better known as its two components the Aux Mélèzes and the Caniapiscau. The Juba river (Somalia) here includes the Ouabi Chebeli (or Uabi Scebeli). The Usumacintas has been separated from the Grijalva (Mexico), the Betsiboka from the Ikopa, the Thelon from the Kazan and the Quoich (Canada), because separate data for water quality or hydrological characteristics are available for these rivers (whereas it is impossible or difficult to find data obtained after their confluence). The Karun River (Iran) is not considered to be a tributary of the Shatt el Arab.

Table II Spellings of river names retained in GEMS/GLORI

Retained	Other spelling	Retained	Other spelling
Asi	Nahr el Asi, Oronte	**Medjerda**	Medjerdah
Aux Feuilles	Leaf	**N. Dvina**	Northern Dvina
Ayerarwady	Irrawady	**N. Dvina**	Severnaya Dvina
Brahmaputra	Jamuna	**Narva**	Velikaya
Brantas	Kali Brantas, Porong	**Natashquan**	Natascouan
Bug	Yuzhnyy Bug	**Nemanus**	Niemen
Cauweri	Kaveri	**Oiapok**	Oyapoque
Chang Jiang (China)	Yang Tze	**Olenek**	Olenjek
Chao Phrya	Chao Phraya	**Olfusa**	Hvita
Cimanuk	Tjimanuk; Manuk	**Omoloy**	Omoloi
Citarum	Tjitarum	**Outardes**	Aux Outardes
Danube	Dunai, Donau, Dunarea	**Patsjoki**	Paatsjoki, Pasvikelva, Pateo Joka
Daugava	W. Dvina	**Penzhina**	Penjina
Dnestr	Dniestr; Dniester	**Petit Mecatina**	Little Mecatina
Dnepr	Dniepr	**Pitalven**	Pite
Douro	Duero	**Petite Riv. Baleine**	Petite rivière de la Baleine
Evros	Meriç, Maritsa	**Pyasina**	Piassina
Ganges	Padma, Ganga	**Qiang Tang, China**	Fushun Jiang
Glama	Glömma	**Rhine**	Rhin, Rhine, Rijn
Grande Riv. Baleine	Grande rivière de la baleine	**Rio Grande**	Rio Bravo del Norte
Hai He (China)	Zhia He	**Rogue**	Rouge*
Hong (Viet Nam)	Hung He, Nhi Ha, Red, Song Koi, Song Hun	**Saint Lawrence**	Saint Laurent
Hualien (Taiwan)	Huallien*	**Santiago**	Rio Grande de Santiago
Huang He (China)	Huang Ho, Hwang Ho, Yellow	**Save**	Sabi
Juba	Guba, Djouba, Giuba,	**Scheldt**	Escaut
Khatanga	Kheta , Chatanga	**Simav**	Susurluk
Koksoak	Aux Mélézes, Caniapiscau	**Sittang**	Sittoung
Komoe	Comoe	**Tana (Norway)**	Tenojoki
Kouilou	Kuilu	**Tan Shui (Taiwan)**	Taan Hsi
Kwanza	Cuanza	**Taymira**	Nysh Taymira
Kysil Irmark (Turkey)	Kisil Irmark	**Tejo**	Tagus, Tage
L. Mecatina	Du Petit Mécatina,	**Tevere**	Tiber, Tibre
L. Mecatina	Little Mecatina	**Thanlwin**	Salween
La Grande	Fort George*	**Tornionjoki Finl.**	Tornealv (Sweden)
La Grande	La Grande rivière	**Winisk**	Winnisk
Luan (China)	Jiung He	**Wisla**	Vistula, Vistule
Maroni	Marowijne	**Wu (China)**	Juilong
Meuse	Maas	**Yesil**	Yesil Irmak
Mindanao	Pulangui	**Zaire**	Congo
Min (China)	Men Jiang	**Zhu Jiang (China)**	Chu Jiang, Pearl, Xi Jiang

* Wrong spelling in some references

Table III Local or national synonyms

Other spelling	Retained here	Other spelling	Retained here
Aux Mélézes	**Koksoak**	Niemen	**Nemanus**
Aux Outardes	**Outardes**	Northern Dvina	**N. Dvina**
Caniapiscau	**Koksoak**	Nysh Taymira	**Taymira**
Chao Phraya	**Chao Phrya**	Olenjek	**Olenek**
Chatanga	**Khatanga**	Omoloi	**Omoloy**
Chu Jiang	**Zhu Jiang (China)**	Orontes	**Asi**
Comoe	**Komoe**	Ouabi Chebeli	**Juba**
Cuanza	**Kwanza**	Oiapoque	**Oypok**
Congo	**Zaire**	Padma	**Ganges**
Djouba	**Juba**	Pasvikelva	**Patsjoki**
Dniepr	**Dnepr**	Pateo Joka	**Patsjoki**
Dniester	**Dnestr**	Pearl	**Zhu Jiang (China)**
Dniestr	**Dnestr**	Penjina	**Penzhina**
Donau	**Danube**	Petite rivière de la Baleine	**Petite Riv. Baleine**
Du Petit Mécatina	**Petite Mecatina**	Piassina	**Pyasina**
Duero	**Douro**	Pitalven	**Pite**
Dunai	**Danube**	Paatsjoki	**Patsjoki**
Dunarea	**Danube**	Porong	**Brantas**
Escaut	**Scheldt**	Pulangui	**Mindanao**
Fort George*	**La Grande**	Red	**Hong (Viet Nam)**
Fushun Jiang	**Qiang Tang (China)**	Rhin	**Rhine**
Ganga	**Ganges**	Rhine	**Rhine**
Giuba	**Juba**	Rijn	**Rhine**
Grande rivière de la Baleine	**Grande Riv Baleine**	Rio Bravo del Norte	**Rio Grande**
Glömma	**Glama**	Rio Grande de Santiago	**Santiago**
Guba	**Juba**	Rouge*	**Rogue**
Huallien*	**Hualien (Taiwan)**	Sabi	**Save**
Huang He	**Huang (China)**	Saint Laurent	**Saint Lawrence**
Huang Ho	**Huang (China)**	Salween	**Thanlwin**
Hung He	**Hong (Viet Nam)**	Severnaya Dvina	**N. Dvina**
Hvita	**Olfusa**	Sittoung	**Sittang**
Hwang Ho	**Huang (China)**	Song Hung	**Hong (Viet Nam)**
Irrawaddy	**Ayerarwady**	Song Koi	**Hong (Viet Nam)**
Isser	**Oued Isser**	Susurluk	**Simav**
Jamuna	**Bahmaputra**	Taan Hsi	**Tan Shui (Taiwan)**
Jiung He	**Luan (China)**	Tage	**Tejo**
Juilong	**Wu (China)**	Tagus	**Tejo**
Kali Brantas	**Brantas**	Tenojoki	**Tana (Norway)**
Kaveri	**Cauweri**	Tiber	**Tevere**
Kheta	**Khatanga**	Tibre	**Tevere**
Kisil Irmark	**Kysil Irmark(Turkey)**	Tjimanuk	**Cimanuk**
Kuilu	**Kouilou**	Tjitarum	**Citarum**
La Grande rivière	**La Grande**	Tornealv (Sweden)	**Tornionjoki (Finl.)**
Leaf	**Aux Feuilles**	Uabi Scebeli	**Juba**
Little Mecatina	**Petit Mecatina**	Velikaya	**Narva**
Maas	**Meuse**	Vistula	**Wisla**
Manuk	**Cimanuk**	Vistule	**Wisla**
Maritsa	**Evros**	Western Dvina	**Daugava**
Marowijne	**Maroni**	Winnisk	**Winisk**
Medjerdah	**Medjerda**	Xi Jiang	**Zhu Jiang (China)**
Men Jiang	**Min (China)**	Yang Tze Kiang	**Chang Jiang (China)**
Meriç	**Evros**	Yellow	**Huang (China)**
Nahr el Asi	**Asi**	Yesil Irmak	**Yesil**
Natascouan	**Natashquan**	Yuzhnyy Bug	**Bug**
Nhi Ha	**Hong (Viet Nam)**	Zhia He	**Hai He (China)**

* Wrong spelling in some references

Homonyms and name confusions
In addition to the problems of name transcriptions into the Latin alphabet, there are on many occasions confusions arising from identical or very similar spellings. Sometimes they may even be located in the same country, as for the Churchill rivers in Canada and the Fitzroy rivers in Australia. Some names, particularly those derived from Spanish, are common and there are many Colorado rivers (coloured river) or Rio Salado (salted river) in the world, sometimes in the same country (two Colorado in the USA in Arizona and Texas, several Salado in Argentina, three Waiau in New Zealand, two Olifants in South Africa etc.).

Sometimes these confusions prevented the identification of the exact location of the river, as for the Waiau or for a few rivers in Taiwan and China. A preliminary list of the possibly confusing names encountered for this inventory is given in Table IV.

5. The GEMS/GLORI data base

5.1 *Structure of the data base*

The first phase of GEMS/GLORI is structured in five sets of data including: the location and the basin characteristics, the gross transport of particulate and dissolved material, the concentrations of dissolved (mg/L) nutrient species, the content of nutrients in the particulate matter (μg/g) and the total nutrient concentrations expressed in mg/L, and major ions in dissolved form (mg/L). The detailed contents are summarized in Table V and given for each river in Annexes VIII to XII.

The data base has been structured to permit the following outputs:
- rivers entering a given ocean or regional sea (Annex VII),
- rivers flowing from a continent or a country (Annex VI),
- rivers listed by latitudes (to check possible climatic effects),
- rivers listed by average run-off (to check possible difference between humid and arid regions),
- rivers listed by Total Dissolved Solids (to check the influence of salinity, i.e. rock solubility), and
- rivers listed by Total Suspended Solids (to check the influence of TSS).

5.2 *Geographic limits of oceans and continents*

Each river is attributed to: (i) a country of river mouth, and (ii) an ocean basin. When river mouths are shared between two countries both names are generally proposed. Limits of continents and ocean basins are those given by the Soviet geographers in the World Water Balance and Water Resources of the Earth (1978) (78.090) and are described below.

Table IV River names occurring in one or more state or country

River A Name	River A Country	River B Name	River B Country	River C Name	River C Country
A la Baleine	Canada (Québec)	**Petite Rivière de la Baleine**	Canada (Québec)	**Grande Rivière de la Baleine**	Canada (Québec)
Aksu	Turkey (Ceyhan trib.)	**Aksu**	(Turkey)	**Aksu**	(Kazakst.) two endorh. rivers
Amgerman	Sweden	**Anguema**	Russia		
Betsiamites	Canada (Québec)	**Bersimice**	Canada (Québec)	**Berbice**	Guyana
Bug (Southern)	Urkraine	**Bug (Western)**	Vistula tribut. (Poland)		
Ceyhan	Turkey	**Seyhan**	Turkey		
Chosui	Taiwan (west side)	**Chosui**	Taiwan (NE side)		
Churchill	Labrador	**Churchill**	Manitoba		
Colorado	Arizona	**Colorado**	Argentina	**Colorado**	Texas
Copper (1)	Alaska	**Coppermine**	Canada	**Coppername**	Surinam
Dong Jiang	China	**Dong Noi**	Viet Nam		
Fitzroy	Western Australia	**Fitzroy**	Queensland (Australia)		
Han	S. Korea	**Han Jiang**	China		
Hay	Mackenzie tributary	**Hayes**	Canada		
Hong	Viet Nam	**Huang**	China	**Han Jiang**	China
Huai	China	**Hai He**	China	**Han**	S. Corea
Kam	Volga tribut.	**Kam**	Africa		
Kemijoki	Finland (Bothnia Gulf)	**Kymijoki**	Finland (Finland Gulf)	**Kem**	Russia
Licungo	Mozambique	**Ligonha**	Mozambique		
Mahakam	Indonesia	**Markham**	Papua New Guinea		
Manamara	Madagascar	**Manamara Sud**	Madagascar		
Meuse	Belgium /Netherland	**Neuse**	USA		
Men (Min)	China	**Mun, Mune**	Mekong tributary		
Musi	Indonesia	**Musa**	Papua New Guinea		
N. Dvina	Russia	**W. Dvina or Daugava**	Latvia		
Nadym	Russia (Arctic Basin)	**Naryn**	Kirghistan (Endorheic)		
Nyong	Cameroun	**Nyanga**	Mozambique		
Omoloy (=Omoloi)	Russia (Artic Ocean)	**Omolon**	Kolyma tributary (Russia)		
Panuco	Mexico	**Patuca**	Honduras		
Parana	Argent./Uruguay	**Paraiba do Sul**	Brasil	**Parnaiba**	Brasil
Pearl	USA	**Pearl River**	China		
Ponnaiyar	India	**Penner**	India		
Pyasina (=Piassina)	Russia (Kara Sea)	**Penzhina (=Penjina)**	Russia (Okhosk Sea)		
Red	Texas (USA)	**Red=Hong**	Vietnam		
Saint John	Canada	**Saint Johns**	USA		
Savannah	USA	**Suwannee**	USA		
Severn	Great Britain	**Severn**	Canada		
Tana	Kenya	**Tana**	Norway	**Tana Lake**	Ethiopia
Tenojoki	Finland/Norway	**Tenniojoki**	Finland		
Waitaki	New Zealand	**Waitako**	New Zealand		

(1) Also a Cooper's Creek, endorheic river in Australia.

Table V Structure of the GEMS/GLORI data base

	Descriptor	Abbreviations in Annexes VIII to XII	Units and remarks
Location and basin characteristics (Annex VIII)	River name	River	see Table I, II, III
	Country of river mouth	Country	
	Ocean and regional sea at river mouth	Ocean	see Table VI and section 5.2, 5.3
	Continent of river basin	Cont.	section 5.2
	Latitude	Lat.	section 5.3
	Longitude	Long.	section 5.3
	Average basin temperature	T	°C, section 5.4
	Average basin precipitation	P	mm/a, section 5.4
	Total river length	L	km, section 5.4
Suspended and dissolved loads (Annex IX)	Basin area	A	Mkm^2
	Average natural water discharge	Qnat	km^3/a
	Average actual water discharge	Qact	km^3/a
	Average runoff (1) (*)	*q1	mm/a
	Average specific discharge (*)	*q2	$L/s/km^{-2}$
	Natural suspended load	Ms nat	Mt/a
	Actual suspended load	Ms act	Mt/a
	Total dissolved load (2) (*)	*Md	Mt/a
	Total suspended solids (3) (*)	*TSS	mg/L
	Total dissolved solids (4) (*)	*TDS	mg/L
Dissolved Nutrients (Annex X)	Dissolved silica	SiO_2	mg SiO_2/L
	Nitrate	$N\text{-}NO_3^-$	mg N/L
	Ammonia	$N\text{-}NH_4^+$	mg N/L
	Orthophosphate	$P\text{-}PO_4^{-3}$	mg N/L
	Dissolved organic phosphorus	DOP	mg P/L
	Dissolved organic nitrogen	DON	mg N/L
	Dissolved organic carbon	DOC	mg C/L
	Dissolved inorganic carbon (*)(5)	*DIC	mg C/L
	Total dissolved carbon (6)(*)	*TDC	mg C/L
Particulate and total nutrients (Annex XI)	Particulate organic carbon (7)	POC	mg C/L
	Dissolved+particulate organic carbon (8)	*DOC+POC	mg C/L
	Total organic carbon (9)	TOC	mg C/L
	Total nitrogen (10)	TN	mg N/L
	Total phosphorus (9)	TP	mg P/L
	Particulate inorganic carbon	PIC	µg/g
	Particulate organic carbon (15)	POC	µg/g
	Particulate nitrogen	PN	µg/g
	Particulate phosphorus	PP	µg/g
	Total Kjeldhal nitrogen (9)	Nk	mg N/L
	Calculated particulate (*) organic carbon (11)	*POC cal	µg/g
Major ions (Annex XII)	Calcium	Ca^{++}	mg/L
	Magnesium	Mg^{++}	mg/L
	Sodium	Na^+	mg/L
	Potassium	K^+	mg/L
	Chloride	Cl^-	mg/L
	Sulfate	$SO_4^=$	mg/L
	Bicarbonate (12)	HCO_3^-	mg/L
	Sum of cations (13) (*)	TZ^+	µeq/L
	Sum of anions (14) (*)	TZ^-	µeq/L

(1): (Q/A), (2): (Q x TDS)/1000, (3): (Msnat x 1000)/Q, (4): Sum of $SiO_2+Ca^{++}+Mg^{++}+Na^++K^++Cl^-+SO_4^=+HCO_3^-$ expressed in mg/L, (5): HCO_3^- x 12/61, (6) TDC = average DOC + Average DIC, (7) : (POC x Ms)/Q or given in references, (8): *TOC = average DOC + average POC, (9): direct measurement on unfiltered sample, (10): Nk + N-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): $Ca^{++}+Mg^{++}+Na^++K^+$ expressed in µeq/L, (14): $Cl^-+SO_4^=+HCO_3^-+NO_3^-$ expressed in µeq/L, (15): (POC (mg/l) x 10^6)/TSS, or given in references.

Ocean limits
Five oceans and five regional seas are identified in GEMS/GLORI as given in Table VI and presented in a set of maps (Annex I).

Table VI Ocean basins and continents attributed to GEMS/GLORI rivers

Code	Oceans
ARC	Arctic Ocean without Hudson Bay
NAT	North Atlantic Ocean, without Baltic, Mediterranean and Black Seas
SAT	South Atlantic Ocean
IND	Indian Ocean without Persian Gulf
PAC	Pacific
	Regional Seas
BAL	Baltic Sea
HUD	Hudson Bay
BLA	Black Sea
MED	Mediterranean
GUL	Persian Gulf
	Continents
EUR	Europe
ASI	Asia
AFR	Africa
NAM	North America and Central America
SAM	South America
OCE	Oceania

The Arctic Ocean basin in Europe is limited by the 63 °N latitude and includes all rivers discharging north between Norway and New Zemblia. In Asia it includes all basins from New Zemblia to the Bering straits and in North America it goes from northern Alaska to the Boothia Gulf and includes the Baffin Bay, although no major river flows into it. The Hudson Bay includes the Hudson Bay proper, the Fox Basin, the Hudson straits, and the Ungawa Bay.

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. In Africa the limit passes just north of the Ogooue which is, therefore, a Southern Atlantic tributary.

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 south west limit of the Pacific is Tasmania.

Continental limits
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 here as in Asia). Oceania includes the whole island of New Guinea (both Irian Jaya and Papua New Guinea), Australia, and all South Pacific Islands. The North American continent

includes here Central America (to Panama included) and all Carribean islands. It must be born in mind here that endorheic basins, particularly the Caspian basin and Central Asia, are not included in the first phase of GEMS/GLORI.

5.3 *Latitude and longitude*

The coordinates (latitudes and longitudes) of the river mouth are essential descriptors which must be known in order to avoid the confusions mentioned previously. Attempts were made as far as possible to give these coordinates for every river listed. Various sources were used: (a) the Kummerli & Frey Atlas which directly gives these coordinates, (b) coordinates of major cities or villages located at river mouths as given by the Times Atlas (such as for the Uruguay, Parana, Nile, Mississippi, Mackenzie, Saint Lawrence), (c) coordinates of gauging stations listed in UNESCO reports on world river discharge, provided they were not too far from the river mouth, and (d) personal determinations from atlases and specific maps (Philippines, Taiwan, Indonesia, Madagascar, etc.) for the remaining rivers. Presently about 530 rivers have coordinates for the river mouths, but a few small basins (of less than 10 000 km^2) are still missing.

5.4 *Data selection for each river*

In many cases multiple values can be found for the same river. This can occur for a variety of reasons:

- Differences in analytical or sampling operations: Although this is not critical for the variables reported here in phase one, it can be critical for most micropollutants, particularly for dissolved metals which can be found with different orders of magnitude depending on data sources (Meybeck & Helmer 1989).
- Differences in station location: For example upstream or downstream of a pollutant source stations affected by salt intrusion.
- Different seasonal surveys (focus on droughts vs focus on flood stage).
- Different survey periods: For example 1981-1984 and 1992-1993. These differences can be due either to hydrological variations or to the real trends in water quality caused by human impacts.

This last point is particularly critical for the suspended load before and after dams (or before and after mining operations which are much less documented). Therefore, in the GEMS/GLORI first stage the natural suspended load (Ms nat) prior to major human activities has been given as well as the actual load (Ms act) resulting from the most recent surveys, both based on the Milliman & Syvitski review (1992).

Even for the most basic variables, as well as for the long term water discharge and total drainage area, some major discrepancies have been found. These sometimes result simply from propagating errors, such as quotation without going to the primary source, which may even be lost or very difficult to find. Important discrepancies or uncertanties are found in Africa and in Asia (as for Indonesia where some Van der Leeden discharges are incorrect by a factor of 10). Due to the economic and sometimes political difficulties of the African continent, river gauging operations (let alone water quality surveys which are absent more than for any other continent) are more and more discontinued and hydrological units are reduced or even dismantled. Recent data for many countries (Somalia, Mozambique, Angola, Zaire, Liberia, etc.) are difficult to find and old data have been used. For the semi-arid regions the river basin areas are sometimes very variable according to various authors who take into account, differently, the non-perennial tributaries which can flow only once every 10 years. This is particularly true for African rivers (Niger, Orange, Juba, Senegal, Nile).

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 closed here at Québec city.

In some river basins the most downstream river quality station is located upstream of the confluence with an important tributary, either directly in the zone of dynamic tidal influence, or still in the river section. When separate water quality data were available from such tributaries they have been considered as specific rivers. This is the case for the Arctic Red and the Peel rivers, both within the Mackenzie basin (North West Territories, Canada). The San Joaquin and the Sacramento (California), and the Thelon and Kazan (North West Territories) and the Grijalva and Usumacinta are also listed separately. The Mobile river has not been split into the Alabama and the Tombigbee, and its major ion composition has been reconstructed from the averages of these two rivers as given by Briggs and Ficke (77.068).

River length can also vary. Here the longest tributary is considered, i.e. Amazon with Ucayali, Mackenzie with Athabaska, Murray with Darling, Nelson with Saskatchewan, Juba with Shaballe (Shebeli or Scebeli), Shatt El arab with Euphrates, Ob with Irtysh. The suspended load data are also very difficult to select. For the Huang He (Yellow river) four different figures have been recently published and/or used by chinese authors and by Milliman & Syvitski (1992). They differ by more than 50 per cent depending on the period of record!

Whenever possible, the data selected for the first line was the most reliable and generally obtained first hand by local engineers or scientists. In this register the whole range of data has generally been given because excluding all other relevant data sources other than those selected by the authors is probably too radical (the authors responsible for data selection could also be wrong). An attempt was made to associate, as far as possible, a reference with each data, and to list other data sources for each rivers to which the interested reader could go for further information. Data are, as far as possible, associated with a time period for the record. Each record consists of three lines: selected data (in bold), reference (in italic), and period of record (plain text).

Each reference starts with a two digit number indicating the publication year (as 78.032 or 89.013) so that the number gives directly the period of publication and, therefore, an indication of the age of the record (see Annex XIII for the list of references).

A very special case is found for the Mississippi, the Red and the Atchafalaya rivers in Louisiana. A branch of the Mississippi, corresponding to about 15 per cent of the water discharge (3 400 m^3/s average) is diverted on its right side and, just downstream, of this divergence, this branch receives the Red River from Texas, a major water body of about 1 761 m^3/s (yearly average). The mixing of the Red river and the Mississippi branch constitutes the Atchafalaya river which enters the Gulf of Mexico west of the present Mississippi river mouth. Here the Red river (240 000 km^2, 55.5 km^3/a) is considered as a specific river and the Mississippi discharge (687 km^3/a) is counted upstream of the Atchafalaya divergence. The total drainage area of the Mississippi listed by the U.S. Geological Survey (3 217 000 km^2) includes the Red river but without it the drainage area is 2 978 000 km^2 (Kammerer, 1986).

Another peculiarity is the Huai river which is a major basin between the Chang Jiang (Yang Tze Kiang) and the Huang He (Yellow) and which cannot be found on some maps (e.g. National Geographic Society, 1991 China map). It is still considered here as a separate river although it enters into lake Hongze then exits as the New Huaishu river, the General Irrigation Canal, and a minor branch tributary of the Chang Jiang.

5.5 *Water quality data reporting*

Calculated data may be found. This applies particularly to TSS which is obtained by Msnat/Qnat where Ms is the annual natural suspended load, generally based on specific surveys focusing on the flood stage, and Q the water discharge (in km^3/a). The "average" TSS, as obtained from regular water quality surveys has been dropped here for two reasons: (i) 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 (ii) the mean values are generally arithmetic and are not discharge-weighted. The actual TSS has also been calculated, although it is of minor significance in many cases due to the lack of reliable discharge data.

The Total Dissolved Solids (TDS) is here the calculated ionic sum plus dissolved silica when available, with alkalinity expressed as mg HCO_3^-/L. The annual load of dissolved solids Md is: Md = TDS x Q. Dissolved Inorganic Carbon (DIC) is computed from HCO_3^- and Total Dissolved Carbon (TDC) which is the sum of DOC + DIC. 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. All the calculated data are identified by an asterix (*) in column headings.

The *analysis of the particulate matter* (POC, PP, PN) can be given either as $\mu g/g$ of suspended matter or expressed as the amount of particulate organic carbon, particulate phosphorus, and particulate nitrogen found in a volume of unfiltered matter (mg/L). 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 the annual nutrient content of particulates. A few authors combine the data of each individual sample on particulate nutrient contents. TSS and water discharge to calculate instantaneous loads of particulate nutrients and then their annual loads, which is the best approach (Meybeck & Thomas 92.050). Yet in some cases PP, or POC, may still be given in mg/L and these loads are simply obtained by the products 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 and given in GLORI (e.g. POC calc. = POC load / TSS load).

The sum of major cations $TZ^+ = Ca^{++} + Mg^{++} + Na^+ + K^+$ (expressed in meq/L) and of major anions $TZ^- = Cl^- + SO_4^= + HCO_3^- + NO_3^-$ (expressed in meq/L) have been calculated. Their comparison allows for the checking of the ionic balance ($TZ^+ = TZ^-$). It must also be noted that for some former analyses, as in former USSR, only the sum as $Na^+ + K^+$ was estimated. Assuming a perfect ionic balance for a few rivers, the K^+ level has been assumed to be equal to 2 mg/L and Na^+ has been derived from this assumption.

5.6 *Data limitations*

Wherever possible the established, 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 occured 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. Rivers of the former USSR provide interesting sets of data for different periods of record, but most of them are now in Russia (see list in Annex VI).

In reality, in most cases, there is little choice of data because the period of records may be even less than one full hydrological cycle (sometimes only a few analyses from separate years are available). In many cases the exact dates for records are completely missing. This information is particularly important for the annual suspended load (Ms) which may vary by one order of magnitude from year to year. The (Ms) data here are mainly (90 per cent) based on the very complete work of Milliman & Syvitski (1992). The period of record is not always available except when the construction of major dams has led to a long term record of suspended load prior to and after daming (referred here, respectively, as Ms natural and Ms actual).

The *annual load computation* is another limit of the data base. These values are calculated on a discharge-weighted basis as recommended by various experts (see GESAMP reports 87.193) and multiple formula have been developed to take into account the concentration vs water discharge relationship when interpolating between sampling periods. Such an attempt has not been achieved here at this stage and "yearly" or "long term averages" have been taken as proposed by the authors. A discharge-weighted average would have required the complete data base of both water quality and discharge at each station. This point is most critical for total suspended solids (TSS) and it is generally not known how the average published values were computed.

Errors in units are also possible. Many countries still report their nitrogen and phosphorus data in nitrate, ammonium and phosphate, while generally $N\text{-}NO_3^-$, $N\text{-}NH_4^+$ and $P\text{-}PO_4^{-3}$ are requested in international programmes. For alkalinity, most regular surveys report it as mg bicarbonate/L considering the current pH range (6 to 8.2 in most rivers). However, GEMS/Water is requesting alkalinity in $CaCO_3$/L which can lead to confusion. The present data base of GEMS/GLORI, phase one contains 10 000 individual data values. *Despite the efforts of the authors there are still numerous errors, mispellings or missing key references, and it is acknowledged that this first register is not yet comprehensive, particularly for the smallest basins (< 50 000 km²). 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.*

6. Present status of GEMS/GLORI data base

For this first report on the GEMS /GLORI data base about 555 rivers have been selected among which 500 exceed a river basin area of 10 000 km^2. The content of the data base is presented in accordance with different criteria (drainage area, continent, water quality parameters, etc.) in the annexes to this report.

In summary, the present status of the GEMS/GLORI is as follows:

(1) About 555 rivers discharging to the ocean were selected here on the basis of at least one of the criteria cited above. Probably more than 95 per cent of rivers exceeding 50 000 km^2 are listed corresponding to a total of 78 million km^2 or about 78 per cent of the continental area drained to oceans.

(2) Locations, features and general characteristics have been determined or collected for about 90 per cent of rivers (at least the drainage area and the average discharge).

(3) Suspended load is known for about 40 per cent of the selected rivers (n = 200).

(4) TDS and major ions are known for about 30 per cent of the selected rivers (n = 180).

(5) Dissolved nutrients are incompletely documented, ranging from 30 per cent of the selected rivers for nitrate to 1 per cent for dissolved organic phosphorus.

(6) Particulate nutrients (POC, PP, PN) are generally not documented for more than 10 per cent of the selected rivers (n = 50).

Although the above clearly indicates the present limits of regional budgets, a first summary of major world river statistics can be given as follows:

- In terms of total water discharge about 80 per cent of the largest 50 rivers ($Q>75$ km^3/a or 2 380 m^3/s) are documented for total dissolved solids and major ions. These represent about 19 000 km^3/a or 50 per cent of the global river discharge.

- In terms of drainage area the 24 largest world rivers (exceeding 770 000 km^2) are, or have been, regularly monitored for TDS and DIC. These represent about 40 per cent of the continental area drained to the ocean.

- When considering the 50 largest rivers in terms of basin area (exceeding 270 000 km^2) the 41 documented for TDS and major ions represent 53 per cent of the continental area.

- In terms of sediment discharge the 10 largest rivers represent about 5.6 Gt/a and the 50 largest rivers 8.35 Gt/a, i.e. 28 per cent and 42 per cent of the total sediment discharge respectively (on the basis of 20 Gt/a for total discharge).

- The present knowledge of the chemical composition (C, N, P) of the particulate material is only available on about 4.5 Gt/a and that is less than 25 per cent of the global discharge of suspended matter.

For this summary it can be concluded that if all 50 rivers, in terms of drainage area and of water discharge, were adequately monitored for the target variables, about half of the global river sample would be covered. The addition of 450 more rivers would increase these proportions from 57 per cent to 78 per cent for drainage area and from 50 per cent to roughly 75 per cent for water discharge.

The limitations of GEMS/GLORI at the present stage are as follows:

- Some major rivers are still not documented or are poorly documented, such as the Ayerarwady (Irrawady), Zambezi, Magdalena, and the Ogoou). Africa is the least documented continent.

- Only annual means are archived here which prevents any analysis of seasonal variation or of concentration-discharge relationships. Long-term trends cannot be considered for the same reason.

- Data quality has not yet been addressed, particularly in respect of the type of survey (sampling methods, number of samples), the processing of the samples and the analytical methods, and the methods used to calculate annual means.

7. Conclusions and recommendations

7.1 *General representativity of the data base*

(1) About 550 rivers discharging to the ocean have been selected so far on the basis of at least one of the criteria (see criteria section 4.1, (ii) to (v)). Probably more than 95 per cent of rivers exceeding 50 000 km^2 and more than 50 per cent of rivers between 10 000 and 50 000 km^2 are listed corresponding to a total of 78 millions km^2 or about 78 per cent of the continental area drained to oceans.

The regions with some discharge or basin area gaps are mostly those with small populations such as Irian Jaya, North Canada and Siberia. For example, the following rivers have been identified in Siberia but corresponding general data have yet been found: Bol. Balakhnya, Fomich, Khanchalan, Khatirka, Ukelayat, Apuka, Chelomdzha, Ulbeya, Kukhtay, Ul'ya, Yudoma, Uda, Tugur! All these river basins, which are marked on major atlases, well exceed 10 000 km^2.

(2) Location features and general characteristics have been determined or collected for about 95 per cent of rivers (at least the drainage area and the average discharge).

(3) Suspended load is known for about 40 per cent of the selected rivers (n = 200). Many more data on TSS are available but they are concerned with small rivers area (A<<10 000 km^2) with less than 5 Mt/a.

(4) Dissolved load and major ions are known for about 30 per cent of the selected rivers (n=180).

(5) Dissolved nutrients are unequally documented, ranging from 1 per cent for dissolved organic phosphorus (DOP) to about 40 per cent for nitrate and silica.

Very few rivers have been analysed for DOP and DON, because these nutrient species are not included in regular surveys although they may equal, or even exceed, the dissolved inorganic nutrients in pristine rivers.

(6) Particulate nutrients are generally not documented (less than 10 per cent of the selected rivers n = 50). Analysis of POC, PN and PP is still mostly carried out within academic studies.

(7) For the well documented variables, regional budgets could be proposed if correct typologies are set up to take into account all causes of variations in the data. For the less-analysed variables, regional budgets to oceans or from continents will not be possible and for these only a global estimate will be made.

The present GEMS/ GLORI report is the result of the personal experience of the authors during 20 years, combined with the ongoing GEMS/Water data collection, and with an important literature search in scientific journals and reports. Yet, by no means should it be considered as definitive and quoted as such. It is the hope of the authors that an in-depth review procedure will be undertaken by the hydrologists and water quality specialists of each country to check and correct these data and to fill the many gaps. This tedious and long process may take time but is essential to ensure the maximum reliability of these data, considering that about 10 000 data points (averages concentrations or station characteristics) have already been collected.

7.2 *Pristine vs impacted rivers*

The GEMS/GLORI register at this stage is mainly focused on present-day data which combine: (i) rivers still in a pristine state (Amazone, Orenoco, Zaire, Lena, Mackenzie), (ii) rivers being impacted by human activities (Saint Lawrence, Ob), and (iii) 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. The rivers of the last category are subject to rapid, and/or drastic, changes and the 5-year or 10-year averages presented here are the appropriate data set on which to assess their evolution.

Of all the water quality descriptors considered in this first phase, nitrate, phosphate and ammonia appear to be the most sensitive to human impacts. Sodium, chloride, and sulfate are also likely to increase markedly. However, since very high values of these ions are also noted in natural conditions, depending on basin lithology and on climate, high levels are not necessarily an indication of pollution.

The register could be developed further in the following directions:

1. *Completing the land/ocean global geochemical cycling of the major elements.* Ca, Mg, Na, K, Cl, and S are presented here in their dissolved form. They should also be presented with the major elements mostly in particulate form (Al, Fe, Mn, Ti, Ca, Mg, Na and K).

2. *Assessing long-term trends of water quality.* In a few rivers the major ions have been analysed for over a hundred years, as indicators of salinization and acidification. Medium term trends (30 years) of nutrients are also documented. Past river trends (medium trends of 20-50 years, long trends of > 50 years) are essential to validate the models of river evolution. However, this information is very dispersed, and not readily available. It is believed that such a data base could be extremely useful for assessments of local- and regional-scale water quality issues and as a basis for collaboration/validation of global scale typologies and modeling.

3. *Adding the potentially harmful inorganic substances.* This concerns many inorganic substances (As, Cd, Cu, Hg, Ni, Pb, Se, Sb, Zn) and other microelements. For these elements it is appropriate to limit data collection at the present stage to particulate material only because: (a) dissolved data are very questionable as to their accuracy and are susceptible to contamination during the dissolved/particulate separation, and (b) 90 to 99.9 per cent of most target elements are found in the particulate phase.

4. *Assessing the data quality with the addition of relevant indicators of data quality.* This could be done with a simple star-ranking which would not overload the data bank.

5. *Completing the data set with tributaries.* Considering the need for a larger data set to build up a typology and to be used for modeling, some data from tributaries could also be stored in the data base if it is particularly well documented and if these basins are homogeneous. This additional data set should cover the potential effects of the full spectrum of human activities.

6. *Completing the data base with large rivers discharging to inland water bodies.* Some of the world's greatest rivers do not discharge to the oceans such as the Volga, Amu Darya, Syr Darya, Chari, Desaguadero, Okawango, etc. However, they are of prime importance for human, economic development and for the conservation of biological diversity. Their characteristics and evolution are sometimes poorly known.

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