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PROVISIONAL INVENTORY DATA OF SURFACE WATER IN THE MEDITERRANEAN

(Prepared by UNESCO)

Preliminary assessment of river inputs to the Mediterranean

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PRELIMINARY ASSESSMENT OF RIVER INPUTS TO THE MEDITERRANEAN

During 1976 and 1977, Unesco's Division of Water Sciences has been charged by UNEP with the assessment of pollutants input to the Mediterranean from land-based sources through rivers. The information collected through these projects has been added to the existing data on river water discharge already obtained through other programmes mainly ruled by the IHP. The purpose of the present report is to sum up the major information collected through these projects, namely:

- a register of major rivers entering the Mediterranean;
- a preliminary estimate of the water input to the Mediterranean for each of the ten hydrographic sub-basins;
- the present state of river quality surveys in the riparian countries of the Mediterranean;
- an assessment of the dissolved pollutants discharged into the Mediterranean through rivers;
- an estimate of the importance of the particulate matter in river pollution and a present review of the quality of river suspended matter in the Mediterranean basin.

A full report with updated information and detailed annexes is foreseen as a working document for the Interregional meeting of IHP National Committees of Mediterranean countries (Rome, October 1978).

1. The Mediterranean Projects

Following the Intergovernmental Meeting on the Protection of the Mediterranean held in Barcelona in 1975, two projects were devoted to the water quality of Mediterranean rivers:

(i) Project MED-1X. Role of sedimentation in the pollution of the Mediterranean.

The following tasks were identified as the immediate objectives:

- to review the role of river sediments in pollutant transfer;
- to review the present knowledge on the quantity and quality of river particulate load discharged into the Mediterranean;
- to co-ordinate the actions of the Mediterranean countries and help them to survey the pollutant load carried by the river particulate matter.

(ii) Project MED-X. Pollutants from land-based sources in the Mediterranean (Unesco was in charge of the section involving river dissolved pollutants input).

Among other tasks, the following were identified:

- to prepare an inventory of land-based sources of pollutants;
- to assess the nature and quantity of pollutants entering the Mediterranean through major rivers.

Information on Mediterranean rivers has also been collected through the World Register of River Inputs to the Ocean (WORRI project sponsored by UNEP) which has compiled a catalogue of the world major rivers (exceeding 300 m^3/S or 100,000 km^2) including their water quality with special reference to the more toxic substances. With the addition of a population criterion (more than two million people within the river basin) about 10 Mediterranean rivers have been listed in WORRI.

The "Discharge of Selected Rivers of the World" published by the IHD has also been a precious source of data on Mediterranean rivers together with National Hydrological Yearbooks and Scientific Publications from various countries.

2. River Water Inputs to the Mediterranean

River discharge to the Mediterranean is one of the major water inflows that has been generally estimated to 30% of total soft-water inflow (direct precipitation and rivers). However this value has been generally based on past water discharge measurements which can be somewhat outdated. In particular the Nile river discharge formerlyy estimated to be around 3000 m^3/s has been drastically reduced by evaporation in Lake Nasser and in irrigated fields of the Delta. Therefore it is important to revise the river water discharge to the sea and to assess the importance of the Nile water discharge decrease in the Eastern part of the Mediterranean where this river is a major inflow.

The following table gives some of the recent water budgets for the Mediterranean sea already showing the overall importance of rivers. However, the inflow of rivers greatly varies between the South-Eastern and Southern Banks and the North-Western Banks.

Table 1. Water budget for the Mediterranean Sea (10^3 m^3/s)

	McGill (1969)	Tixeront (1970)	Lacombe and Tchernia (1972)
Evaporation	92	95	-
Precipitation	33	28	-
River runoff	14	16	-
Net inflow through :			
Dardanelles	6	6	6
Gibraltar	40	45	54.4

The Mediterranean sea is usually divided into Eastern and Western basins, separated by the Siculo-Tunisian sill and the sill of Messina. It has been found very useful for the study of river inputs to the Mediterranean to divide these basins into compartments more or less defined by their morphological structure and by their hydrological characteristics. Ten compartiments have been considered in the Mediterranean sea proper (see figure 1) I. Alboran Sea II. North Western Basin III.South Western Basin lV.Tyrrhenian Sea V. Adriatic Sea Vl. Ionian Sea VII. Central Basin VIII. Aegean Sea 1X. North Levantin Basin and X. South Levantin Basin. For each sub basin a river discharge assessment has been realized as follows:

I. Alboran Sea
II. North Western Basin
III. South Western Basin
IV. Tyrrheanian Sea
V. Adriatic Sea.
VI. Ionian Sea.
VII. Central Basin
VIII. Aegean Sea.
IX. North Levantin Basin
X. South Levantin Basin.

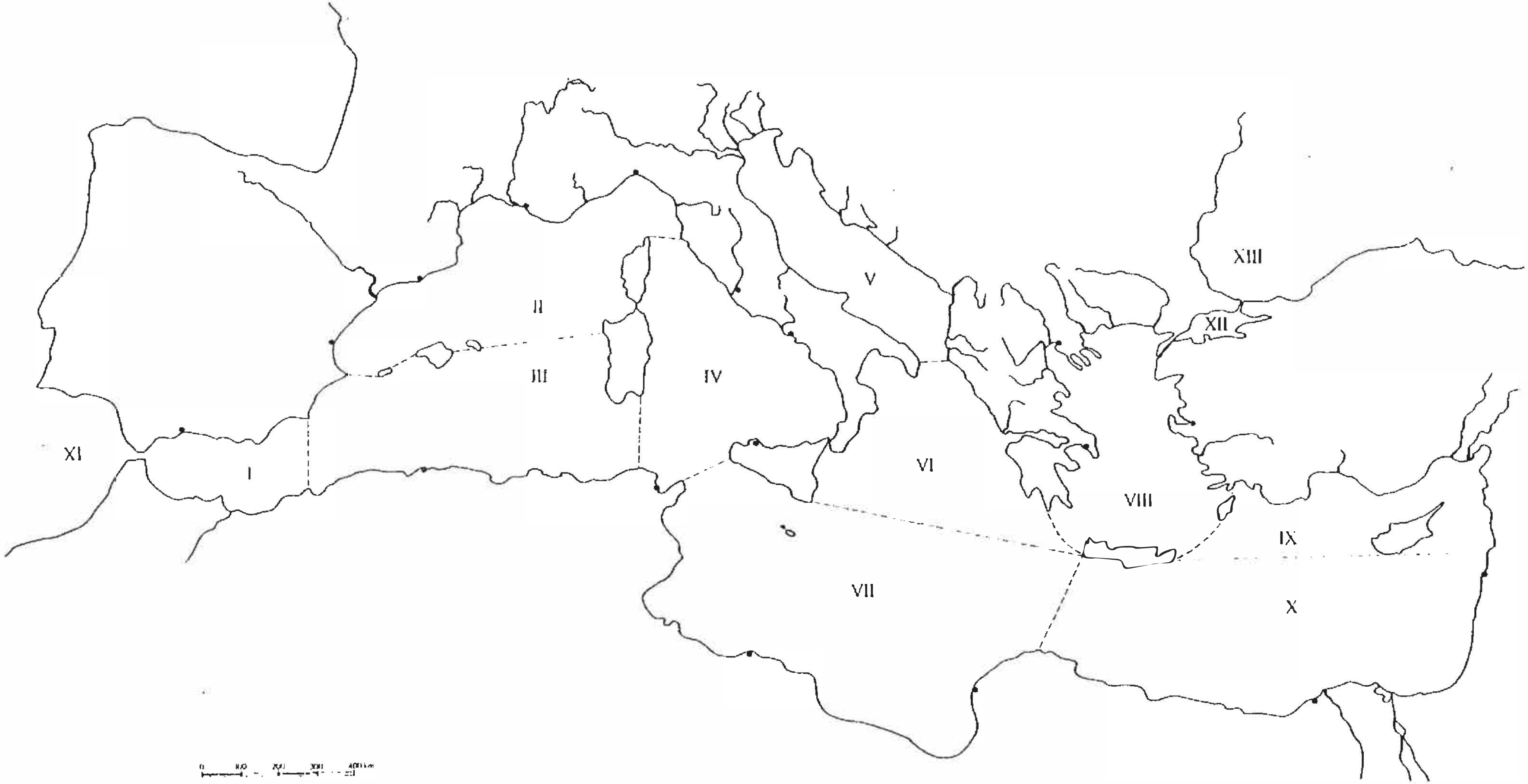

FIGURE 1: REGIONAL ENTITIES OF THE MEDITERRANEAN PROPER AND ADJACENT SEA AREAS

(i) Already existing water budgets have been directly incorporated as such, particularly for Spain (R. Heras, 1970) and Italy (Anonimous 1967).

(ii) When known, individual river water discharges have been used (e.g. Rhone, Evros, Ebro...)

(iii) When no information on river water discharge was available and/or for areas of direct water runoff to the sea in between gauged rivers a regional estimate of the specific discharge per unit area has been taken on the basis of results from (i) and (ii). This specific discharge has then been multiplied by the drainage area.

(iv) The Nile river discharge estimate was a tricky problem because of the two major Delta branches, the irrigation channels in the Delta, and the direct input from coastal lakes. Taking into account various measurements by theEgyptian authorities, the water discharge would be at the present time no more than 550 m^3/s which is considerably less than the natural discharge (2830 m^3/s).

Due to the variety of hydrological information for each sub-basin the precision of the assessment presented in Table 2 (p.7) generally varies from 20% to 30%.

It clearly results from Table 3 (see p.8) that despite its very great drainage area - one of the world's greatest - the Nile no longer plays an important role in the Mediterranean river water budget. About 60% of the river water enters the Mediterranean in the North Western basin and the Adriatric Sea which corresponds only to 12% of the total drainage area.

The South-Levantin basin is a matter of major concern: if our estimate of present day Nile discharge is correct, the water input from land would be reduced by 80%.

2.2. Major rivers entering the Mediterranean

About 500 rivers discharging to the Mediterranean have been considered in the preliminary phases of projects MED 1X and MED X. A full catalogue is now under preparation, a preliminary list of water discharge and drainage area is given in table 8 (see annex). The first ten Mediterranean rivers (table 4 see p.8) only now represent 44% of the present day total water discharge from land. As it will be seen later these rivers are not yet fully monitored for water quality, even so, the consideration of these rivers solely would not give a comprehensive view of land-based pollutants to the Mediterranean.

3. Water Quality Surveys of Mediterranean Rivers

3.1. The global water-quality survey in the Mediterranean.

Several meetings of experts have led to the selection of water-quality parameters of two types: black list substances which are highly toxic, grey-list substances that can be detrimental to man or to the environment. To these were added general parameters that give a good indication of the water quality. The full list is given in table 5.

TABLE 2
Tentative budget of surface water input to the Mediterranean
Bilan approché des apports en eau de surface à la Méditerranée

Regions	total area	total disch.	specific discharge
	$10^3\ km^2$	$m^3.s^{-1}$	$l.s^{-1}.km^{-2}$
I. ALBORAN			
Spain	18.4	70	3.8
Morocco	63	107	1.5
Algeria	20.5	20	1
Total	101.9	197	1.9
II. NORTH-WESTERN			
Spain	145	701	4.8
France (+ Corsica)	125	2080	16.5
Italy	7.4	232	31.4
Total	277.4	3013	10.9
III. SOUTH-WESTERN			
Algeria	79	118	1.5
Tunisia	2.2	4	1.5
Italy (Sardinia)	14.9	140	9.4
Spain	18.6	28.5	1.5
Total	114.7	290	2.5
IV. TYRRHENIAN			
France (Corsica)	6.4	96	15
Italy (Sardinia)	9.2	86	9.3
Italy (Mainland)	66.7	1013	15.2
Italy (Sicilia)	5	30	6
Total	87.3	1225	14.0
V. ADRIATIC			
Italy	154.3	3116	20.2
Yugoslavia	55	1462	26.6
Albania (1)	21.3	617	29
Total	230	5195	22.6
VI. IONIAN			
Italy (Mainland)	23	287	12.5
Italy (Sicilia)	7	35	5
Albania (1)	9.1	263	29
Greece	32.6	518	15.9
Total	71.7	1103	15.4
VII. CENTRAL			
Tunisia	32.2	32	1.0
Italy (Sicilia)	13.7	73	5.3
Total	45.9	105	2.3
VIII. AEGEAN			
Greece (Mainland)	146	980	6.7
Greece (Crete)	9.1	45	5
Turkey (2)	60.3	458	7.6
Total	215	1463	6.9
IX. NORTH-LEVANTIN			
Turkey (2)	93.4	710	7.6
Cyprus	9.1	45	5.0
Syria	5.7	23	4
Total	108.2	778	7.2
X. SOUTH-LEVANTIN			
Lebanon	7.8	24	3
Israel	10.3	10	1
Greece (Crete)	3.3	16	5
Egypt (Nile in 1977) (3)	2900	500	0.17
Total	2920	550	0.19
Total Region I to X.			
Nile in 1950	4172	16249	3.9
Nile in 1977	4172	13919	3.3
(1) Total ALBANIA	30.4	372	28.7
(2) Total TURKEY	154	1170	7.6

(3) Estimate for 1977 (Rosetta Branch - Delta Lakes).

Table 3. Relative Importance of Mediterranean Water Input from Land for each Mediterranean Sub-basin

	% total drainage area (1)	% total present water discharge
Alboran	2.4	1.4
North-Western	6.5	21.6
South-Western	2.9	2.1
Tyrrhenian	2.7	8.8
Adriatic	5.5	37.3
Ionian	1.7	7.9
Central	1.1	0.75
Aegean	5.1	10.5
North Levantin	2.6	5.6
South Levantin (1)	69.9	4.0

(1) including total Nile drainage area

Table 4. Characteristics of Major Mediterranean Rivers ranked according to their Present Day Water Discharge

River	Drainage area (km^2)	Water discharge (m^3/s)	Specific dischar ($l.s^{-1}\ km^{-2}$)
Rhone (France)	95 600	1712	17.9
Po (Italy)	70 000	1550	22.2
Ebro (Spain)	84 000	570	6.8
Nile (Egypt)	2960 000	$\simeq$550	0.19
Neretva (Yugoslavia)	-	378	-
Drini (Albania)	12 400	342	27.6
Evros (Greece)	55 000	311	5.65
Tevere (Italy)	16 500	234	14.2
Adige (Italy)	12 000	231	19.25
Ceyhan (Turkey)	20 000	215	10.75

As said before it has not been possible to consider only the major rivers for a general assessment of land-based pollutantsources because they would correspond only to about 45% of the river discharge. Therefore 60 rivers have been selected which represent the whole range of river water regime, land use, human settlements etc. in the Mediterranean basin (see table 7 in the annex).

3.2. State of monitoring

Among the 17 riparian Mediterranean countries at least nine have already organized regular river water quality surveys. Lebanon, Malta, Monaco and Libya have no selected rivers so far, while no precise information has been obtained from Albania, Algeria and Turkey. Complete information on the state of monitoring including frequency of measurements for each water quality parameters is given in table 8 (see annex) for 60 selected rivers. It can be seen from table 8 that the types of river surveys are very different from one country to another. Rivers from Cyprus, France, Italy and Spain are usually monitored on a monthly basis while the other rivers are only monitored a few times a year.

Nearly all important rivers (more than 100 m^3/s) are now monitored, but the water quality data are still poor for some of them, for a variety of reasons. The major gaps on water-quality information are the following:

Albania: Drini, Semani, Vjöge – no information on water quality;

Egypt: Nile – difficulties in assessing the average quality of the water going to the sea (several Nile branches, channels, and delta lakes);

Greece: Akhelos, Aliakmon, Axios, Evros, Ionios – only restricted analyses (some parameters of the grey list);

Turkey: Ceyhan, Manavgat, Seyhan, Sussurluk – no information on water quality;

Yugoslavia: No information so far at Unesco.

It must be noted that some countries (Cyprus, Israel, Spain) have greatly modified their existing river surveys so as to meet the requirements of the project MED-X. Particularly, Spain has begun a regular survey of all Black and Grey lists substances on six major rivers on a monthly basis. However, despite these efforts and the existing surveys prior to the Mediterranean Action Plan, such as in Italy and France, there remain some very important gaps in our knowledge of the river water quality.

The majority of the selected rivers are regularly monitored for the general water quality determinants (pH, conductivity, dissolved oxygen).

Concerning the Grey list substances, the most commonly measured parameters are BOD and COD, then nitrate, ammonia, total phosphorous. Many analyses of Cu, Cr and Zn are realized. However, the following elements are still very seldom monitored in the Mediterranean rivers: total nitrogen, phenols, detergents and nearly no information is available, except for Spanish rivers, for Ni, organophosphorous compounds, TOC and mineral oils.

The Black list substances are even less studied. Some information is available for As, Pb, Cd, sparse analyses exist for Hg, and nearly nothing

TABLE 5: List of pollutants to be monitored in Mediterranean rivers.
Liste des polluants à mesurer dans les rivières méditerranéennes.

	dissolved pollutants polluants dissous	particulate pollutants polluants particulaires
Black List Liste Noire	As Hg Pb Cd PCB other chlorinated organic compounds autres composés organo-chlorés	As Hg Pb Cd PCB other chlorinated organic compounds autres composés organo-chlorés
Grey List Liste Grise	Cu Cr Ni Zn BOD; COD or TOC phenols, detergents, mineral oils huiles minérales organophosphorous compounds composés organophosphorés total P; total Kjeldahl N; nitrates; ammonia ammoniaque total suspended solids; matière totale en suspension total volatile solids matière organique en suspension.	Cu Cr Ni Zn

is known on organochlorine compounds, except for some Spanish rivers.

This clearly emphasizes the urgent need for the survey development of the more toxic substances, either heavy metals and As or toxic organic compounds. The nutrients monitoring must also be increased. It is important to note that these gaps have also been identified on a world-wide basis during the WORRI project (World Register of Rivers Discharging to the Ocean). They are mainly due to financial and technical problems leading to the lack of analytical capacity of such parameters on a routine basis (no analytical apparatus, lack of trained technicians, technical problems for sampling and pre-treatment).

3.3. State of Water Quality

It is far outside the scope of the present report to survey each Mediterranean river individually. Moreover the quality of information is highly variable and is lacking for most of the South and Eastern Bank rivers. Among the well monitored rivers some of them can be considered as unpolluted waters, others seem to be effectively used as open air sewers (see table 9 in annex).

Evidence of pollution has been found in some of the major Mediterranean rivers draining industrial regions (Rhone, Po, Llobregat). However, due to the high specific discharge the concentration levels are very seldom higher in these rivers than usual drinking water standard.

Locally some very small rivers can be extremely polluted particularly by industrial wastes. The water quality monitoring of such rivers is particularly important and should indeed be considered like direct urban or industrial sewers.

3.4. Dissolved pollutant discharge to the Mediterranean

In view of the scarcity of data on water quality it is very difficult to compile a total pollutant load to the Mediterranean sea. Moreover the MED X project were asked to assess the river pollutant input for each black and grey list substances and for each sub-basin. Therefore, interpolations have been used in some regions where water quality was poorly known and desk computations were applied when no data could support any interpolation.

Three major types of rivers have been identified for the assessment of the pollutant discharge to the sea (table 9) The first type represents the natural background value in a non-polluted Mediterranean region. These data are based mostly on some Spanish rivers and on a literature review of natural concentrations. The second type is an average of the Rhône, Po, Llobregat and Ebro concentrations. This last figure will be considered as typical of rivers draining highly populated and industrialized regions. The third type represents heavily polluted rivers. As noticed before this type would be more representative of urban and/or industrial sewage. It is only given here as an example of ultimate deterioration of river quality by man.

The pollutant budget for each sub basin has been realized as such:

TABLE 6: Rivers to be surveyed for the assessment of the pollutant input from land-based sources to the Mediterranean.
Rivières sélectionnées pour l'estimation des apports polluants des rivières à la Méditerranée.

	polluants dissous dissolved pollutants	polluants particulaires particulate pollutants
Albania	not determined	not determined
Algeria	Cheliff, Harrach, Macta, Mazafran, Seybousse, Soummam, Isser	Cheliff, Seybousse
Cyprus	Vassilikos	no rivers selected
Egypt	Nile (several stations)	Nile; coastal lakes
France	Argens, Aude, Gepeau, Hérault, Onb, Rhône, Tech, Tet, Var	Aude, Hérault, Rhône
Greece	Akheloos, Aliakmon, Axios, Evros, Nestos, Pinios, Strimon	Evros
Israel	Hadera, Qishon	no rivers selected
Italy	Adige, Brenta, Pescara, Piave, Po, Tevere	Adige, Arno, Po, Pescara, Tevere
Lebanon	not determined	not determined
Libya	no rivers selected	no rivers selected
Malta	"	"
Monaco	"	"
Morocco	Kiss, Laou, Moulouya, Nekor, Rhis	Moulouya
Spain	Besos, Ebro, Fluvia, Guadal-horce, Jucar, Llobregat, Mijares, Segura, Ter, Tordera, Fluvia	Ebro, Llobregat
Tunisia	Medjerda	Medjerda
Turkey	Seyhan, Ceyhan, Buyuk-Menderes, Manavgat	Seyhan, Ceyhan, Buyuk-Menderes
Yugoslavia	Cetina, Krka, Neretva, Zrmanja	Neretva

(i) Monitored rivers

Individual loads for each river have been obtained as a first estimate by multiplication of the yearly average water discharge by arithmetical means of each water quality determinant. This method is obviously biased since the dissolved contents average are not discharge-weighted, however, in view of the low sampling frequency (no more than one a month for most rivers) it has not been thought necessary to weigh the average content.

(ii) Non-monitored rivers and interfluves

- region with regular water quality surveys: regional average water quality has been computed on the basis of existing surveys, and extrapolated to non-monitored rivers. This method has been applied for Italy, France and Spain.

- region without regular water quality surveys: the pollutant load is entirely based on computation taking into account the specific water discharge as defined in Table 2 and two extreme sets of water quality typical of unpolluted Mediterranean rivers and of industrialized regions as given in Table 8 (see annex). Therefore minimum and maximum values are given.

The tentative budget of dissolved pollutants carried by rivers to the Mediterranean (Table 7 p. 14) , is obviously a rough estimate. Concerning the major part of the Black list substances this budget is only known with an order of magnitude. Moreover there is an analytical problem for some of these elements (particularly for Hg and Pb) as the river particulate matter is sometimes partly considered as dissolved material. Moreover there are frequently contamination problems occurring during sampling and analyses. This could result in an overestimation of the so-called "dissolved content".

The main result of this first assessment is the importance of the pollution load to the North Western basin, and to the Tyrrhenian and Adriatic seas. If the four best accurate budgets are considered (BOD, COD, total N and total P) it clearly appears that the total amount of pollutants received by these three sub-basins is generally around 70% of the total amount of pollution received by the Mediterranean as a whole. There is a combined effect of both high water discharge in these regions and of generally higher levels of contamination in these rivers.

4. Contamination of particulate matter in the Mediterranean rivers.

4.1. Importance of river particulate matter in pollution studies.

The possibility of quantifying the flux of pollutants through the aquatic ecosystem depends upon the identification of the various phases that act as reservoirs of chemical substances. There are basically three major reservoirs: i.e. dissolved reservoir (water and dissolved load), particulate reservoirs (suspended and bottom sediment) and biological reservoir (plankton, benthos, nekton...)

The assessment of pollutant behavior within these reservoirs, as well as the flux of material from one to the other, and the boundary conditions of the system are the pre-requisites of a holistic knowledge of pollutant pathways in the aquatic environment. Moreover, this will help to implement a monitoring programme and to provide a basis for prevention and eventual control of pollution.

Table 7:

TENTATIVE BUDGET OF DISSOLVED POLLUTANTS CARRIED BY RIVERS TO THE MEDITERRANEAN (t.year)
BILAN ESTIME DES APPORTS DES RIVIERES EN POLLUANTS DISSOUS A LA MEDITERRANEE (t/an)

Regions	I. ALBORAN min.	max.	II. NORTH WESTERN min.	max.	III. SOUTH WESTERN min.	max.	IV. TYRRHENIAN min.	max.	V. ADRIATIC min.	max.	VI. IONIAN min.	max.
WATER DISCHARGE $km^3.year^{-1}$	6.2		95		9.1		38		163		35	
BOD	17000	41000	450000		19000	52000	130000	227000	365000	753000	64000	192000
COD	7000	73000	1100000		19000	103000	190000	770000	735000	1150000	64000	384000
Total P	700	6000	115000		950	8600	5000	27500	35600	123000	3200	32000
Total N	8000	20000	340000		5400	22400	20000	70000	155000	350000	16000	80000
Detergent	27	1200	2000	14000	11	1700	2600	7600	4000	23000	< 32	6400
Phenols	< 6	30	180	300	< 8	40	< 32	160	100	600	< 32	160
Hg	0.6	3	9.5	50	0.85	4.2	3.2	16	90	130	3.2	16
Pb	30	45	800		42	76	160	290	1080	1480	160	290
Cr	6	60	280	800	8.5	85	32	320	15	150	32	320
Zn	180	360	2400		255	510	960	1900	6300	9500	960	1900

	VII. CENTRAL min.	max.	VIII. AEGEAN min.	max.	IX. NORTH LEVANTIN min.	max.	X. SOUTH LEVANTIN min.	max.	TOTAL MEDITERRANEAN $10^3.year^{-1}$ min.	max.	accuracy level of budget / niveau de fiabilité du bilan
WATER DISCHARGE $km^3.year^{-1}$	3.3		46		24.5		17.3(1)		438 (1)		
BOD	10000	30000	92000	275000	50000	150000	42000	112000	1250	2300	xxx
COD	10000	60000	92000	550000	50000	300000	47000	222000	2300	4700	xxx
Total P	500	5000	4600	46000	2450	24500	3000	30000	170	400	xx
Total N	2500	12500	23000	115000	12000	60000	12000	47000	700	1100	xx
Detergents	< 5	1000	< 46	9200	< 25	5000	200	3650	9	75	0
Phenols	< 5	25	< 46	230	< 25	120	16	100	0.45	1.8	x
Hg	0.5	2.5	4.6	23	2.5	12	1.7	8.5	0.04	0.2	0
Pb	25	45	230	415	120	220	90	155	2.7	3.8	x
Cr	5	50	46	460	25	250	17	170	0.5	2.7	x
Zn	150	300	1400	2800	750	1500	535	1050	14	22	x

(1) included Nile discharge in 1977
xxx good; xx sufficient; x poor; 0 very poor
xxx bon; xx moyen; x insuffisant; 0 très insuffisant

In this connection, the particulate reservoir is one of the major sub-systems of the aquatic environment, and requires special attention. The comparison between dissolved and particulate elemental concentrations shows that most heavy metals and organic pollutants are enriched in the solid phase by two or three orders of magnitude. When the relative amount of pollutants transported in river waters and in the suspended sediments are compared, the importance of sediment is clearly seen.

The chemical behaviour of pollutants linked to the particulate phase and their biological availability depends highly on the speciation of the particulate pollutant: adsorption onto the smallest particles (clays, colloids....) and onto particulate organic matter coprecipitation with oxides, hydroxides on the coarser particles forming coatings on sand grains; insoluble organic compound and crystalline matrix.

Any change in the chemical composition or in the physical parameters of a water body may cause a pollutant to be released from the particles. Among the variations of chemical parameters able to affect the pollutant-particle association, pH variation plays a significant role. Diagrams of the solubility of metals as a function of pH indicate that, in acid waters, hydroxides, carbonates and sulphides become unstable and metals may pass into ionic form. Such pH variations can be caused by either bacterial decomposition of organic matter or by release in the rivers of industrial acid effluents.

Another possibility of particulate pollutant mobilization occurs in the deposited sediments where there is often an increase of dissolved concentrations in interstitial waters, caused by solubilization processes, which generate an upward diffusive flux of pollutants through the benthic boundary layer which can be enhanced by resuspension of bottom deposits, e.g. floods or bioturbation, or by anthropogenic action, e.g. dredging activities.

Finally when the river reaches the ocean through an estuary, new geochemical conditions are present that may once again modify both the dissolved and particulate contents of pollutants in water. These processes can sometimes lower the dissolved input to the ocean by 50%. Conversely some pollutants can be mobilized from the particulate phase so that the dissolved concentration be increased.

The recent studies of the particulate matter have clearly shown that as a whole the particulate matter is the major means of transport of pollutants in rivers. The proportion of some of the Black and Grey lists substances carried with the particulate matter are figured in table 10 for some of the major world rivers and for some Mediterranean rivers. Usually more than 70% of the various metals are carried by the suspended material.

However the study of the river particulate matter still presents some difficulties concerning the separation of particulate and dissolved phases, the estimate of natural background values of heavy metals, and chemical samples treatment to estimate the amount of pollutant that could be easily mobilized or uptaken by the biota.

4.2. State of river particulate matter contamination in the Mediterranean basin

4.2.1. Origin of data

Expert meetings in Rome and Paris for the Med IX projects have selected the parameters to be surveyed in river particulate matter and the rivers to be monitored (tables 5 and 6). However only very few rivers have been so far studied. Published data have been obtained for the Rhone and Aude (France) and for several Israelian rivers.

Moreover, and following the recommendations of the Med IX project and the recommended sampling and pre-treatment procedures for particulate pollutant analysis prepared jointly by the International Laboratory of Marine Radioactivity (IAEA, Monaco) and the Division of Water Sciences of Unesco, some rivers were sampled and their sediment analysed. They include the Medjerdah (Tunisia) and Ebro and Llobregat (Spain). Rivers A and B (country not identified) were analyzed by the IAEA.

Some results are presented in table 11, the attention must be drawn to the different chemical treatments of the particulate matter: preferential leaching with dilute acid that could correspond to the easily mobilized fraction and total content including the crystal matrix.

4.2.2. Preliminary results

Four of the major Mediterranean rivers (Po, Adige, Rhone, Aude) do not appear heavily polluted in comparison to the Rhine river. However, there is good evidence of contamination for the following rivers: Adige (Zinc), Po (Zinc), Rhone (Zinc, Lead and locally Copper, Chromium, Mercury), Aude (Chromium). The Gadura river in Israel seems to be badly contaminated. However none of these rivers present extreme heavy metals' contents as found in some American or European rivers receiving mine tailings or industrial wastes.

It clearly appears from this preliminary study that the particulate matter in Mediterranean rivers can play a major role as pollutant carrier but, due to the scarcity of data, it is not possible at the present time to make any estimate of the total amount of pollutant carried to the sea.

5. General conclusions of river inputs to the Mediterranean

5.1. Major results

River water input: after the drastic reduction of the Nile water discharge that has lowered by 80% the water input in the South Levantin basin, the major water input (60%) enters the Mediterranean through the North Western basin and the Adriatic sea which corresponds to only 12% of the total drainage area.

Water quality survey: dissolved pollutants are regularly surveyed in the Mediterranean countries. However only Cyprus, France, Israel, Italy and Spain have developed intensive surveys of a majority of Black and Grey lists substances on which reliable pollutants loads computation can be based.

The general parameters (pH, conductivity, dissolved oxygen) are the most commonly measured while the Black List substances are very little known, particularly the organochlorine compounds.

State of water quality: there is a full range of water quality in the Mediterranean rivers from very pure and unpolluted to very severely polluted. For these latter rivers the "quality" approaches that of urban and industrial sewers. Major rivers, although already contaminated, do not present very high pollutant levels such as those found in the Seine or Rhine rivers.

Dissolved pollutant discharge has been computed from measured loads in many countries and extrapolated by desk computations for some others. The main result is the importance of the pollutant load received by the three North Western basins (North Western Basin s.s., Tyrrhenian sea and Adriatic sea which amount to about 70% of the estimated total pollutant load to the Mediterranean. This figure has been calculated for BOD, COD, total N and total P and can probably be extrapolated to the other water quality determinants.

River particulate matter contamination: its study is still beginning in the Mediterranean Basin. However its importance as a major pollutant carrier is already evident. The first results show similar patterns as for dissolved pollutants: there is a great range of contamination, the major rivers are already slightly contaminated but their level of contamination does not seem to be alarming.

5.2. Need for better knowledge of river inputs.

Our knowledge of river water discharge has been greatly improved during the last ten years partly due to the co-ordinating action of the IHD and IHP. The actual Nile river discharge is still a question mark and careful investigations should be realized in the Delta. This discharge is now of secondary importance for the whole basin but is still the only river water input to the South Levantin basin.

River water quality monitoring must be realized on a routine basis on the Eastern and Southern Mediterranean rivers. In the Northern Mediterranean countries surveys must be extended to 24 samples per year or even more. This frequency is absolutely needed to see any trend of water quality in future years. However there is no need to increase the sampling frequency as far as a better water quality reliability is achieved. For many of the monitored parameters there is a great variability between one laboratory and another and the no. 1 priority is to proceed to an inter-calibration exercise including sampling, storage and pre-treatment methods.

Intensive efforts must be made in the whole of the Mediterranean basin to survey the most toxic substances still very poorly known: organochlorine compounds, Hg and also Cd, Pb and As. Concerning the pollutants carried by the suspended matter there is an urgent need to establish regular surveys at least for the major Mediterranean rivers.

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For this first assessment a sampling frequency of at least four times a year would seem to be the minimum. The fate of particulate and dissolved pollutants carried by rivers when entering the ocean should be studied in the Mediterranean environment and a pilot project could be set up in a polluted delta.

The first assessment of river dissolved and particulate pollutant inputs to the Mediterranean is still know with an order of magnitude for most of the important parameters. Therefore no improvement of water quality can be identified in the future unless additional water quality surveys are undertaken very rapidly.

-References -

ANONIMOUS(1967) : Standard average values of monthly and yearly flows of Italian rivers. In Water for Peace, Washington, vol. 4, 399 - 406.

ANONIMOUS: Discharge of selected rivers of the World, vol I, II, III, IV. Studies and Reports in Hydrology. Unesco Press.

BOTHNER M.H., CARPENTER R. (1973): Sorption-desorption reactions of mercury with suspended matter in the Columbia river, in "Radioactive Contamination of the Marine Environment" I.A.E.A., Vienne.

CRANSTON R.E., BUCKLEY D.E. (1972): Mercury pathway in a river and estuary. Environ. Sci. Technol. 6, 274-278.

DE GROOT A.J. et al. (1976): Processes affecting heavy metals in estuarine sediments, in Estuarine Chemistry, J.D. BURTON, P. LISS Ed., Academic Press.

FÖRSTNER U. MULLER G.(1974): Schwermetalle in Flüssen und Seen. 225 pp. Springer Verlag, Berlin.

GIBBS R, (1973) Mechanisms of trace metal transport in rivers. Science, N.Y., 180, 71-73.

MCGILL D.A. (1969) A budget for dissolved nutrient salts in the Mediterranean sea - Cahiers Oceanographiques 21, 6 543-554.

HERAS, R.(1970) Données pour l'étude du bilan hydrique en Espagne. In World Water Balance, Proc. Reading Symposium. Unesco Press, 332-342.

KRONFELD J., NAVROT J.,(1975). Aspect of trace metal contamination in the coastal rivers of Israel., Water Poll. 4, 1, March 1975.

LACOMBE H., TCHERNIA P (1972). Caractères hydrologiques et circulation des eaux en Méditerranée. In D.J. Stanley (ed) The Mediterranean Sea, Dowden, Hutchinson and Ross, Stroudsburg, 25-36.

MARTIN, J.M. Contribution à l'étude des apports terrigènes d'oligo-éléments stables et radioactifs à l'océan. Doct. ès Sciences, Paris 1971.

MARTIN, J.M. MEYBECK, M.(1977). Elemental Mass Balance of material carried by world major rivers, Submitted to Marine Chemistry .

MEISCH H.U., REINLEW, BIELIG H.J.(1978). Schwermetalle in Sedimenten der Saar. Deutsche gewäss. Mitt. 22, 1, 2-8.

MONACO A. Géochimie des milieux d'estuaires: comparaison entre les suspensions fluviatiles et les dépôts pro-deltaïques de l'Aude(Languedoc), Chemical Geology 20 (1977), 45-55.

TIXERONT J. (1970) Le bilan hydrologique de la Mer Noire et de la Mer Mediterranée. Cahiers Oceanographiques 22 (3) 227 - 237.

TREFRY J.M., PRESLEY B.J. Heavy metals transport from the Mississippi river to the Gulf of Mexico. In Marine Pollutant transfer H.L. WINDOM, R.A. DUCE ed. Lexington Books, Lexington, Massachussetts.

SMITH J.D. et al. (1971) Mercury in sediments from the Thames estuary. Environ. Pollut. 4, 153-157.

VERNET, J.M., SCOLARI G., RAPIN F. (1976). Teneur en métaux lourds dans les sédiments des rivières suisses du Rhône français et de ses affluents, Bul. BRGM, Section III, No. 1, 2.

WINDOM M.L. et al. (1971) Transport of trace metals to the atlantic ocean by three south eastern rivers. S. East Geol. 12, 169-181.

Table 8 Selected Mediterranean rivers, with hydrological characteristics and their state of river water quality surveys (dissolved substances).
A: drainage area (10^3 km^2) and Q: water discharge (m^3/s)
⊗ unknown frequency; + 1-5 samples per year; ++ 6-11 samples per year; +++ ≥ 12 samples per year.

Caractères hydrologiques des rivières méditerranéennes et état des programmes de surveillance de la qualité des eaux
A: superficie du bassin (10^3 km^2) Q: débit (m^3/s)
⊗ fréquence inconnue; + 1-5 échantillons par an; ++ 6-11 échantillons par an; +++ ≥ 12 échantillons par an.

			BLACK LIST						GREY LIST																				
	Q	A	As	Hg	Pb	Cd	PCB	DDT	P_t	N_t	N-NO3	N-NH4	Cu	Cr	Ni	Zn	org P	Phen	BOD	COD	TOC	det	oils	coli	T	SM	DO	pH	Cond.
ALBANIA																													
Drini	342	12.4	No information on water quality so far																										
Mati	91	2.4																											
Semani	113	5.3																											
Vjöse	182	5.2																											
ALGERIA																													
Cheliff	40	43.7						will be monitored																					
Harrach								monitored (?)																					
Macta	2.7	4.0		⊗					⊗										⊗	⊗									
Mazafran	13.8	1.9						will be monitored																					
Seybousse	13.4	5.9						will be monitored																					
Soummam	24.9	8.4						will be monitored																					
Isser																													
CYPRUS																													
Vassilikos	0.12	0.15	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++				+++	+++			+++	+++	+++
EGYPT																													
Nile	948	2960							+++		+++	+++								+++				+++				+++	+++
Roseta B.	(?)	–	⊗					⊗	⊗	⊗	⊗	⊗							⊗				⊗				⊗		
Damietta B.	202	–	No information so far																										
Delta Lakes	380	–	No information so far																										
FRANCE																													
Argens	16	2,53	+++		+++	+++			+++	+++	+++	+++	+++	+++		+++		+++	+++			+++		+	+++		+++	+++	+++
Aude	66.0	1.79	+		+	+			+++	+++	+++	+++	+	+		+		+++	+++			+++		+	+++		+++	+++	+++
Hérault	53.4	2,55	+++		+++	+++			+++	+++	+++	+++	+++	+++		+++		+++	+++			+++		+	+++		+++	+++	+++
Orb	31.9	1,15	+		+	+			+++	+++	+++	+++	+++	+++		+++		+++	+++			+++		+++	+++		+++	+++	+++
Rhône	1712	95,0	+++		+++	+++			+++	+++	+++	+++	+++	+++		+++		+++	+++			+++		++	+++		+++	+++	+++

TABLE 8

	Q	A	As	Hg	Pb	Cd	PCB	DDT	P_t	N_t	N-NO3	N-NH4	Cu	Cr	Ni	Zn	org P	Phen	BOD	COD	TOC	det	oils	coli	T	SM	DO	pH	Cond.
			BLACK LIST						GREY LIST																				
Tet	13.7		+		+	+			+++	+++	+++	+++	+	+		+		+++	+++			+++		+	+++		+++	+++	+++
Var	65.4	1.83	+++		+++	+++			+++	+++	+++	+++	+++	+++		+++		+++	+++			+++		+	+++		+++	+++	+++
GREECE																													
Acheloos	167		No information on monitoring																										
Aliakmon	133				●									●				●	●								●	●	●
Axios	134	23.0			●							+++		●				●	+++	+++	+++						●	+++	+++
Evros	311																		●								●		
Nestos	33	3.6																						+				+++	+++
Pinios	102		will be monitored																										
Strimon	73	1.5																										+++	+++
ISRAEL																													
Kishon	0.46	0.68	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	++	+		+	+	+	+	+	+	+	+
Hadera	0.3-0.6	0.52	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+		+	+	+	+	+	+	+	+
ITALY																													
Adige	231	11.9[illegible]	+	+	+++	+	+	+	+++		+++	+++	+++	+++					+++	+++		+					+++		
Brenta	73	1.5[illegible]																	●	●							●		
Pescara	54	3.12																	●	●							●		
Piave	88	3.33							++	++	++	++							++	++							+++		
Po	1550	70	+	++	++			++	+++	+++	+++	+++	++		++	++		+++	+++	+++		+++	+++	+++	+++	+++	+++	+++	+++
Tevere	234	16.5						+	+++		+++	+++					+		+++	+++		+++		+++	+++	+++	+++	+++	+++
LEBANON			No river selected so far																										
MOROCCO			No information on water quality																										
Kiss	19.6																												
Laou	28	0.94																											

TABLE 8 PART 2

	Q	A	As	Hg	Pb	Cd	PCB	DDT	P_t	N_t	N-NO3	N-NH4	Cu	Cr	Ni	Zn	org P	Phen	BOD	COD	TOC	det	oils	coli	T	SM	DO	pH	Cond.
			BLACK LIST						GREY LIST																				
Moulouya	50	52																											
Nekor	2.2	0.63																											
Rhis	7,5																												
MALTA								no	selected river																				
MONACO								no	selected river																				
LYBIA								no	selected river																				
SPAIN																													
Nesos	1.3	1.0							+		+	+		+				+	+++	+++		+			+++	+++	+++	+++	+++
Ebro	550	84	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++		+++	++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
Fluvia	6.8	1.0							+		+	+		+				+	+++	+++		+			+++	+++	+++	+++	+++
Guadal-horce	8,5	2,85	++	++	++	++	++	++	++	++	++	++	++	++	+	++	+	+	+++	+++	++	++	++	+++	+++	+++	+++	+++	+++
Jucar	40	21.5	++	++	++	++	++	++	+	++	++	++	++	++	++	++	++	++	+++	+++	+	++	++	++	+++	+++	+++	+++	+++
Llobrega	22	4.9	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+++	++	+	+	+		+++	+++	+++	+++	+++
Mijares	113	2.5							+			+	+	+		+	+	+	++	++					+++	+++	+++	+++	+++
Segura	7.3	14,9	+	+	+	+	+	+	+	+	+	+	+	+				+	+++	+++	+	+	+	+	+++	+++	+++	+++	+++
Ter	14.5	1.8							+		+	+		+				+	+++	+++		+			+++	+++	+++	+++	+++
Tordera	3.8	0.8							+		+	+		+				+	+++	++		+			+++	+++	+++	+++	+++
Turia	14.6	6.3	+	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	+++	+++	+++	+++	+++
TUNISIA																													
Medjerdah	31	22.1																	+							+++		+++	+++

TABLE 8 PART 3

	Q	A	BLACK LIST						GREY LIST																				
			As	Hg	Pb	Cd	PCB	DDT	P_t	N_t	N-NO3	N-NH4	Cu	Cr	Ni	Zn	org P	Phen	BOD	COD	TOC	det	oils	coli	T	SM	DO	pH	Cond
TURKEY			No information on water quality so far																										
Buyuk Menderes	100	23,8																											
Cayhan	230	19,8																											
Manavgat	129	0.93																											
Seyhan	188																												
Susurluk	132																												
YUGOSLAVIA Cetina	89								●		●								●	●				●	●	●	●	●	●
Krka	51																												
Neretva	355								●		●								●	●				●	●	●	●	●	●
Zrmanja	40																												

Q discharge ($m^3.s^{-1}$); débit
A drainage area (10^3 km^2); superficie du bassin
Pt total Phosphorus; phosphore total
Nt total Nitrogen ; azote total
org P organo-phosphorous compounds; composés organophosphorés
phen phenols
det detergents
T temperature
SM suspended matter; matières en suspension
DO dissolved oxygen; oxygène dissous
cond. conductivity ; conductivité

TABLE 8 PART 4

Table 9 . Examples of three types of river from the Mediterranean countries according to their pollution level. Dissolved contents in $\mu g/l$.

Exemples-types du niveau de pollution des rivières Méditerranéennes - (teneurs en solution en $\mu g/l$).

	unpolluted river (1) **rivière non-polluée (1)**	river in industrial region (2) **région industrielle (2)**	heavily polluted river **rivière très polluée**
As	1	2	-
Hg	0.1	0.5	0.4
Pb	5	9	45
Cd	0.5*	5	10
Pt	100	1000	8000
N. min. tot.	500	2500	45000
Cu	10	45	70
Cr	1	10	15
Ni	2	20*	80
Zn	30	60	220
phenol	0.0	5	150
BOD	2000	6000	100000
COD	2000	12000	200000
TOC	5000*	25000*	-
detergent	0.0	200	2000
min. oil	0.0	1000	20000

* estimates

(1) unpolluted rivers in Spain and world averages of natural dissolved content.

(2) average of dissolved contents of the Rhône, Po, Llobregat and Ebro rivers.

(3) average of dissolved contents of the Besos, Hadera and Kishon.

*** estimation**

(1) rivières non-polluées d'Espagne, et moyennes mondiales des teneurs naturelles en solution.

(2) moyenne des teneurs en solution du Rhône, Po, Llobregat et Ebro.

(3) moyenne des teneurs en solution du Besos, Hadera et Kishon.

Table 10. Ratio (in percent) of the river particulate pollutant load over the total pollutant load in some world rivers compared to Mediterranean rivers.
Participation (en pourcent) des polluants particulaires à la pollution totale apportée par certaines rivières Méditerranéennes comparée à celle de quelques rivières du monde.

River	BLACK LIST / LISTE NOIRE				GREY LIST / LISTE GRISE			
	Pb	As	Hg	Cd	Zn	Ni	Cr	Cu
Rhine (The Netherlands(1)	72	56	56	44	37	23	70	64
Rhine (Germany)(2)	83	-	61	28	44	24	80	50
Thames (3)	-	-	92	-	-	-	-	-
Southeastern rivers (U.S.A.) (4)	-	-	-	-	87	82	92	53
Amazon (5)	-	-	-	-	-	97	90	93
Yukon (5)	-	-	-	-	-	98	87	97
Columbia (6)	-	-	52	-	-	-	-	-
Mississipi (7)	99.2	70.2	-	88.9	90.1	94.7	98.5	91.5
Saar (8)	97		64	78	36	25	60	70
Adige (9)	90	-	-	-	-	-	80	86
Po (9)	83	-	-	-	91	-	-	47
Rhône (10)	70	-	-	-	64	-	61	68
Llobregat (11)	43	6	-	24	15	-	13	7
Ebro (11)	44	7	-	4	4	-	3	1

(1) De Groot, Allersma and Van Driel (1973).
(2) Förstner and Müller (1974);
(3) Smith et al.(1971)
(4) Windom et al (1971)
(5) Gibbs (1973)
(6) Bothner and Carpenter (1973)
(7) Trefry, Presley (1976)
(8) Meisch, Reinle,Bielig (1977)
(9) CNR Italy average of 3 and 6 analyses
(10) from J.M. Martin (1971) and J.P. Vernet et al (1977)
(11) Centro de Estudios Hidrográficos, Spain, first estimate based on a single analysis.

Table 11 Contents of heavy metals in suspended and deposited sediments from mediterranean rivers ($10^{-6}g.g^{-1}$)
Teneurs en métaux lourds dans les sédiments en suspension ou déposés de quelques rivières méditerranéennes ($10^{-6}g.g^{-1}$)

River / pollutant	FRANCE (c)		IAEA (a)		ISRAEL (3) (b)						World average(5)
	Rhône(1)	Aude(4)	river A (2)	river B (2)	YARGON	AYYALON	ALEXANDER	MADERA	QISHON	GADURA	Moyenne mondiale
Arsenic			-	-	-	-	-	-	-	-	5
Mercury	0.5-1.5	1.2	1.7	0.8	n.d	n.d	.15(.07-.30)	.56	(0-0.1)	(0-0.3)	-
Lead	270		60	8	28(20-48)	81(12-266)	13(7-22)	14(5-25)	29(9-72)	158(93-275)	150
Cadmium			2.3	0.4	n.d.	7.9(.1-16)	n.d.	n.d.	(0-4)	55(7-123)	1
Copper	93	112	50	8	2.8(1.6-3.3)	6.7(2.3-16)	1.7(2.1-3.0)	7(3-13)	14(3-48)	17(6-43)	100
Chromium	76	112	20	4	2.8(1.9)	35(12-124)	13(11-17)	14(12-17	18(3-56)	294(62-610)	100
Nickel			30	6	1.0(1-4)	17(8-60)	6.3(6-7)	9(6-12)	15(11-19)	22(17-31)	90
Zinc	1310	2100	180	40	52(12-83)	196(49-323)	45(48-72)	87(42-176)	130(20-325)	931(365-1500)	350

(1) MARTIN J.M. (1971), VERNET et al. (1977).
(2) I.A.E.A. Monaco Laboratory, average of 3 analysis, Northwestern Mediterranean Rivers, leached suspended matter.
Laboratoire de Monaco de l'AIEA, moyenne de trois analyses après attaque ménagée de suspensions de deux rivières se jetant dans le Sous-Bassin Nord-Ouest.
(3) KRONFELD J. and NÁVROT J. (1975) average of 3-9 analysis.
(4) MONACO A. (1977).
(5) MARTIN J.M., MEYBECK M. (1978).
(a) suspended sediment, leaching with diluted HCl acid.
matière en suspension, attaque ménagée par HCl dilué.
(b) deposited bank sediment (< .17 mm, leaching with hydroxylamine-hydrochloride in 25% acetic acid).
sédiment déposé sur les rives (< 0,17 mm) attaque ménagée par hydroxylamine en milieu acétique.
(c) total content of the particulate matter.
teneur totale dans la matière en suspension.