

6.3 Surface water degradation

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Streams, lakes, reservoirs and wetlands are used and exploited in a variety of ways. They contain cultural and religious values that are essential. Exploitation of surface waters contributes to the deterioration of water quality and changes in ecology. The natural patterns of seasonality and other variations cause mismatch between supply and demand of water.

Surface water in the hydrologic cycle

Surface water resources – rivers, other streams, lakes, reservoirs, and wetlands – are a very dynamic part of the global water cycle. The climatic variability, both seasonal and annual, affects greatly the quantity and quality of surface waters. Basically, the input comes from rainfall, and the output from evaporation to the atmosphere and flow to the oceans. The water cycle also includes flow and storage in soil, in the ground, as snow and as ice.

In this chapter, quality and quantity issues of surface waters are summarized; the former ones in some more detail, because Chapters 2.3 to 2.5 present an overview of water quantity in the global scale and in the study regions, even by country.

Quantity

Climatic issues determine the input to the surface waters, and partly also the output. Wet and rainy seasons or years cause floods and dry ones are the reason of droughts. In addition, changes in vegetation and land use cause long term changes in the water retention, infiltration, and other properties of watersheds, and therefore also in water quantity. The most marked quantitative changes are, however, due to man-made constructions such as reservoirs, dams, water transfer systems and so forth.

In the global level, the construction of reservoirs has increased the stable runoff—the flow in driest seasons—by 1/3 (Figure 2.2b). By this, the floods have been cut down too, because flood waters can be stored to reservoirs to be used in the dry seasons.

The water consumption, however, has grown to such an extent, that many of the world's big rivers are today exploited so severely that they discharge practically no water at least seasonally to the oceans or seas. Such rivers include Amu-Darya and Syr-Darya in Central Asia, Nile and Niger (Global Water Partnership 2000) in Africa, Colorado in North America, Huang He in China, and Ganges-Brahmaputra in In-

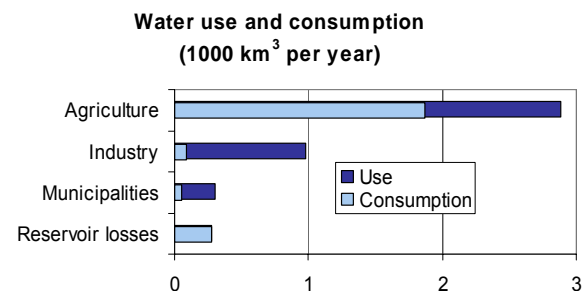
dia (Postel 1996). In fact, most of the world's rivers have changed markedly their flow pattern due to man's influence (Figure 10.1d).

Only a part of the water that is withdrawn for human use returns to the watersheds. The rest is evaporated into the atmosphere. Postel et al. (1996) have estimated, that around 51% of all water used by humans will not be available to other end-users (Figure 6.3a). For more discussion on the topic, see Chapters 2.3 to 2.4. Figure 2.3b shows water use vs. withdrawal data for each country in the study regions.

Figure 6.3a

Water use and consumption

Postel et al. (1996) have estimated, that around ½ of all the water used will not be available for other users. They call this proportion as consumed water. Agriculture is the greatest consumer, accounting for over 4/5 of the total water consumption.



Many Asian metropolises such as Bangkok, Calcutta, and Dhaka that are practically floating on water, but where the water contamination in almost all conceivable ways makes the water use very difficult (cf. Box 10.3b). Water transfer systems even from distances of hundreds of kilometers are being constructed to meet the urban needs. Large-scale water scarcity problems are created in the regions from which water is conveyed away.

In Thailand's central plain, which is one of the rice bowls of the world, large irrigation systems are these days useless in dry seasons, because their water is

drawn away to meet the rapidly growing Bangkok's expanding demands. The city itself is sinking, due to overdraft of groundwater, and its ample surface waters are too heavily polluted for any other use but navigation.

Quality

Surface water quality problems consist of several different issues. This is due to the great diversity of lakes, reservoirs and rivers, the wide range of needs and preferences in society for the utilization of surface water, and the complexity of aquatic ecosystems. The changes are caused by point source polluters such as industries and settlements that have a sewerage system; non-point polluters such as agriculture, or through the atmosphere. The most common water quality problems are:

- *Eutrophication* caused by the abundance of nutrients and other agents of enhanced primary production.
- *Oxygen depletion* caused by degradation of organic matter in water.
- *Hygienic problems* due to pathogenic organisms such as viruses, bacteria or protozoa.
- *Salinization* caused by high concentrations of ions such as calcium, sodium, chloride and sulphate.
- *Acidification* due to atmospheric deposition of SO₂ and NO_x or by industrial, mining or natural emissions.
- *Toxic or cumulative compounds* such as heavy metals or other trace elements, radioactive compounds, halogenated hydrocarbons or water-borne toxins.
- *Suspended material and turbidity* caused by inorganic or organic matter.
- *Changed thermal conditions* due to thermal pollution, flow control or changed climate.

The principal driving force in water quality management is the need to resolve the potential conflict arising from the specific demands and impacts of various activities on water quality, often under water scarcity. Many water uses suffer from poor quality but have no direct influence on it, while many cause water quality problems but are not harmed by them (Tables 6.3a and 6.3b).

Table 6.3c presents a checklist designed by Varis and

Somlyódy (1996). It is applicable to the screening of lake and reservoir water quality problems as a part of the Environmental Impact Assessment (EIA) process. Table 6.3d shows the various interconnections between the numerous factors and driving forces of water quality.

Table 6.3a

Impacts of surface water quality to uses.

Typical influences of water quality problems on most frequent uses: eutrophication, oxygen depletion, hygienic problems, salinization, acidification, toxic / cumulative substances, turbidity and suspended matter, thermal pollution. - = low or occasional influence, -- = marked influence.

Use	Eutrophic.	Oxyg. Depl.	Hyg. Prob.	Salinization	Acidification	Toxic subst.	Turb.&susp.	Therm. Poll.
Conservation	--	--	--	--	--	--	--	--
Recreation	--	--	--	--	--	--	--	--
Fisheries	--	--	--	--	--	--	--	--
Aquaculture	-	--	--	-	-	--	-	-
<i>Withdrawal:</i>								
- Households	--	--	--	-	-	--	-	-
- Municipalities	--	-	-	-	-	--	-	-
- Irrigation, etc.	-	-	--	--	-	--	-	-
- Industry	-	-	-	-	-	-	-	-
Transport	-						-	
Flood control							-	
Hydropower							-	
Cooling basin								-
Waste transport and disposal	-							

Table 6.3b

Impacts of uses to surface water quality.

Use	+ = low or occasional impact, ++ = high impact							
Conservation								
Recreation								
Fisheries								
Aquaculture	++	+					+	
<i>Withdrawal:</i>								
- Households								
- Municipalities								
- Irrigation, etc.	+			+				
- Industry								
Transport			+			++	+	
Flood control	+	+					+	+
Hydropower	+	+		+			++	+
Cooling basin	+	+				+		++
Waste transport and disposal	++	++	++		+	++	++	

For an itemized description of constituents of water quality and water use standards, see Thanh and Tam (1990a) and McCutcheon et al. (1992). Various national and international agencies and authorities release their own standards, which are typically use-specific.

Table 6.3c

Surface water quality impact assessment

*Cross-impact matrix for surface water quality impact assessment: + = same direction, - = opposite direction, * = indefinite, case specific or unknown direction (Varis and Somlyódy 1996).*

Specification	Problem impacted *)							
	Eutrophic.	Oxyg. Depl.	Hyg. Prob.	Salinization	Acidification	Toxic subst.	Turb.&susp.	Therm. Poll.
Climatic inputs								
Temperature	+	+	*	+				+
Humidity				-				+
Solar radiation	*	+		+			+	+
Precipitation				-	+	*		-
Wind	*	-		+	*	*	*	-
Thermal and hydraulic								
Stratification	*	*	*			*	*	*
Ice-free period	+	*	*				*	+
Hydrologic								
Floods	*	*	+	-	*	*	*	-
Droughts	*	*		+	*		*	+
Erosion, loading	+	+	+	+	*	+	+	
Retention time	+	+	*	+	*	+	*	+
Water level	-	-	*	-	*	-	*	-
Chemical								
Oxygen	-	-	-			-	-	
Carbon dioxide	*	*		+	+			
Nutrient enrichment	+	+	*				+	
Salinity				+	-	*		
pH	+	+	-		-	*	*	
Ecological								
Growth season length	+	+	*				*	+
Food chains, succession	*	*	*				*	
Blue-green algae	+	+	+			+	+	
*) Problems								
Eutrophication (E)		+			-	+	+	
Oxygen depletion (O)	+					+	+	
Hygiene (H)								
Salinization (S)					-	*		
Acidification (A)	-					+	-	
Toxicity (X)								
Turbidity (M)	*	+	+			+		
Thermal (T)	+	+	*	+				

Global comparisons are difficult

It is fairly complicated to carry out any global comparisons on water quality issues and problems, due to the many-sidedness of the question, and given the present data sets. Water quality consists of a number of criteria, and their relation to the very varied water uses, differ greatly.

These comparisons are not as accurate as many national ones, such as (see China's national assessment in Box 6.3a), but they allow regional comparisons. And they are in rapid development all the time. As an example, the water quality indicators for the twenty-

one rivers of the study regions (Figure 6.3c) that are among the eighty-two rivers in the world that are included in the summary table of the GEMS/WATER database (GEMStat 2006) are shown in Figure 6.3d.

This system was established in 1976 by WHO, UNESCO, WMO and UNEP, and includes 287 river stations, sixty lake stations, and seventy-six ground-water aquifers. A digital water quality atlas is also available.

Water quality in freshwater assessments

Water quality deterioration has been almost neglected in contemporary global water assessments (Chapter 2.4). This is a severe handicap of those assessments. Water may be abundant, but the decreased quality is often a major obstacle for human uses as well as to the ecological balance in a watershed. No amount of water is sufficient, if its quality is deteriorated.

One exception is the UNEP/GEF study on global international waters. Global Environmental Facility initiated the Global International Waters Assessment (GIWA) project with the aim of providing comparable information on the state of international waters. The methodology was designed to integrate as many problems and their root causes as possible using a causal chain approach. The assessment is based on the result of expert panels that evaluate the status of the waters using a standard protocol. The world is divided into sixty-six regions, which include the major rivers and the adjacent marine areas.

The GIWA project is still ongoing at the time of writing, but the available results with respect to the study regions are collected in Table 6.3e. Among those sixty-six regions, eleven lie in the five study regions China, S Asia, SE Asia, the Nile basin countries and W Africa.

With all respect to GIWA's results, one cannot avoid some cynicism to the results by looking them a bit more carefully: one among myriad examples is that Lake Chad—even though having lost 90% of its surface area—does not seem to be considered as a particularly problematic area by GIWA. One could continue with such strange examples.

Rehabilitation of damaged watersheds

With the intensive exploitation of nature, it is typical that the so-called natural aging processes of the ecosystems are dramatically accelerated. Many water quality problems such as eutrophication, turbidity, and oxygen depletion, change the ecosystems in the same direction as their natural aging. For instance, the eutrophicated Lake Tuusulanjärvi, Finland, ages with a rate of roughly 100 times of the natural rate. In

global scale, an example can be taken from the loss of biodiversity (see Chapter 6.5).

Many water quality problems are also related to the opening of material cycles. This issue is discussed in more detail in Chapter 6.1.

Pollution prevention was mentioned as one of the leading contemporary paradigms in water management in Chapter 3.1. With the other mentioned paradigms it addresses the observation from innumerable cases that remediation of damaged watersheds, lakes, rivers, etc., is typically exceedingly more expensive than prevention of the damage beforehand (Box

6.3b). The dilemma is, that usually there is no political pressure to take the actions before the problems turn visible to the society.

In many industrialized countries, formerly constructed rivers and watersheds are being increasingly rehabilitated closer to their natural state. Thus tendency is a response to the recognition of the importance of natural ecosystems in issues such as self-purification of water, flood control, and landscape formation. Naturally, it also reflects the changed values and tastes concerning the exploitation of surface waters.

Box 6.3a

Required reversal of environmental degradation in China

China is extremely short of natural resources, given its dense population. An analysis of the Chinese Academy of Sciences noted that "China's environmental pressures already exceed the critical equilibrium limits of many ecosystems" (Chinese Academy of Sciences 1992; Niu and Harris 1996). Reversing the environmental degradation is an expensive exercise. The World Bank (1997) estimated, that 1-2% of GDP will be required to address water and air pollution. This is a large figure, but it must be seen against the economic losses due to pollution, which equals 8% of GDP.

China has suffered from severe inefficiencies in its production system. A high volume of emissions in relation to produced wealth is a clear indication of this (Box 6.1a).

The consequences of high emissions and high population density are clearly visible in China's water, air and land resources. The nitrate and ammonium concentrations doubled in the Huang He and the Yangtze rivers in the 1980s (Zhang et al. 1995). Frequent, severe eutrophication problems can be observed in all major Chinese river systems. Surface water quality problems are most oppressive in the water-scarce parts of China (Figure 6.3b). This tendency is enhanced by the rapidly deteriorating groundwater situation—both in terms of quality and quantity—in the North China Plain (ADB 2000).

Figure 6.3b

China's Northern Plain suffering from severe water scarcity has also great water quality problems

Water quality in major river basins of China in 1996 (after Shen and Dafoe 1998). The Chinese surface water quality classification was used (classes 1 & 2: good, class 3: moderate, and classes 4 & 5: poor).

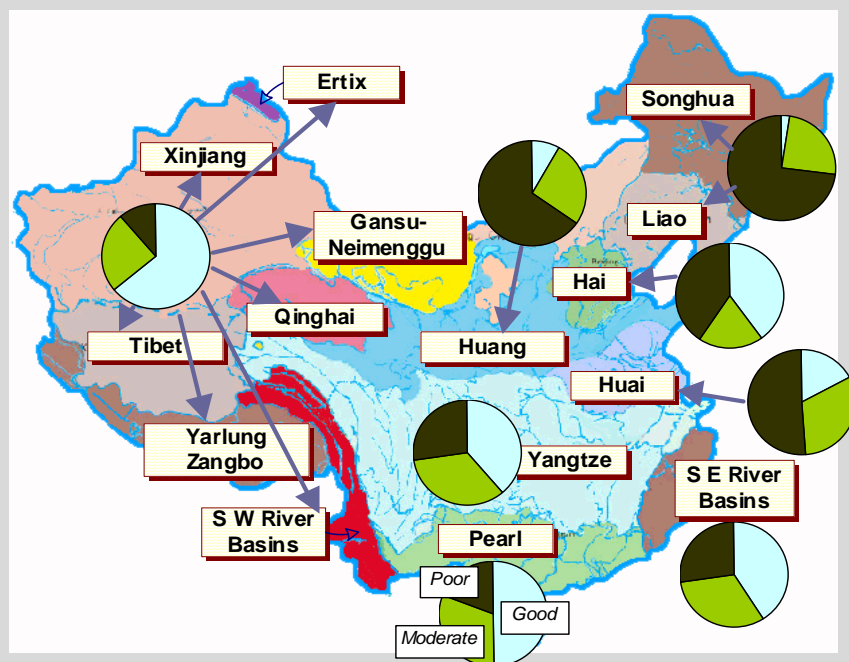


Table 6.3d

Surface water quality interconnections

Cross-impact matrix for interconnections among factors of surface water quality: + = same direction, - = opposite direction, * = indefinite, case specific or unknown direction (Varis and Somlyódy 1996).

Influence from	To ^a	St	If	Fl	Dr	El	Rt	Wl	Ox	Ca	Nu	Sa	pH	Gs	Fs	Na
Climatic inputs																
Temperature		*	+	*	*		*	*	*	*		+		+	*	+
Humidity		*		+	-	*	-	+				*			*	
Solar radiation		*	+	*	*				*	*			*	+	*	*
Precipitation		*	*	+	-	+	-	+	*	*	*	-	*		*	
Winds		*	+	*	*	+			*	*	*	*	*		*	*
Thermal & hydraulic																
Stratification	(^a)	St	If	Fl	Dr	El	Rt	Wl	Ox	Ca	Nu	Sa	pH	Gs	Fs	Na
Ice free period	St		*				*	*	*	*	*		*	*	*	*
	If	*		*		*			*	*	*		*	+	*	+
Hydrologic																
Floods	Fl	*	+		-	+	-	+	*	*	*	-	*	*	*	*
Droughts	Dr	*	*	-		*	+	-	*	*	*	+	*	*	*	*
Erosion, loading	El	*	*	*	*				*	*	+	+	*	+	*	*
Retention time	Rt	*	*	-		*			*	*	+	+	*	+	*	+
Water level	Wl	*	*	*	-	*	*		*	*	-	-	*	*	*	-
Chemical																
Oxygen	Ox					*				*	-		*		*	*
Carbon dioxide	Ca					*			*			+	-		*	*
Nutrient enrichment	Nu								*	*		+	*		*	+
Salinity	Sa	*	+						*	*	*				*	*
pH	pH					*			*	*	*	*			*	+
Ecological																
Growth season length	Gs								*	*	*		*		*	+
Foodchains, succession	Fs								*	*	*		*		*	*
Nuisance algae	Na								*	*	+		+		*	

Figure 6.3c

Selected, major rivers of the study regions

1 = Chang Jiang, 2 = Hong He, 3 = Huang He, 4 = Xi Jiang, 5 = Brahmaputra, 6 = Ganges, 7 = Indus, 8 = Cauveri, 9 = Godavari, 10 = Krishna, 11 = Mahanadi, 12 = Narmada, 13 = Tapti, 14 = Chao Phaya, 15 = Irrawaddy, 16 = Mekong, 17 = Salween, 18 = Nile, 19 = Chari, 20 = Niger, 21 = Senegal. For selected data from the GEMS/WATER database, see Figure 6.3d.

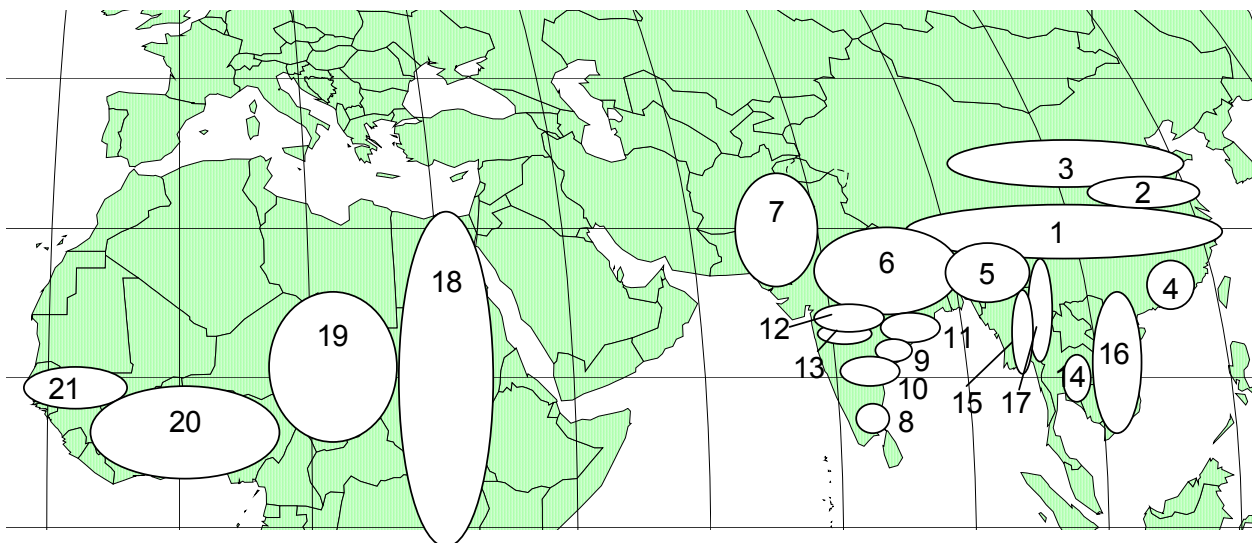


Figure 6.3d

Water quality comparison of the major rivers of the study regions

Water quality and watershed data from the GEMS/WATER database (GEMStat 2006). The data has been scaled to the average situation within the eighty-two world's major rivers included in the summary table of the database. This was done by subtracting the mean value of each indicator from each river's indicator value, and dividing it by the standard deviation of that indicator. For instance, the value eight of the TSS indicator for the Huang He river in China means, that the river contains eight times more TSS than the standard deviation among all the rivers included. All the values that exceed one can be considered exceptional. Area = area of the watershed, Discharge = water flowing through the intersection in which the measurement is made, Runoff = water flow as scaled with watershed area, TDS = total dissolved solids, TSS = total suspended solids, (f) = mass flow, Na = sodium, K = potassium, Ca = calcium, Mg = magnesium, Cl = chloride, SO₄ = sulphate, HCO₃ = bicarbonate, SiO₂ = silicate, PO₄-P = phosphate, NO₃-N = nitrate.

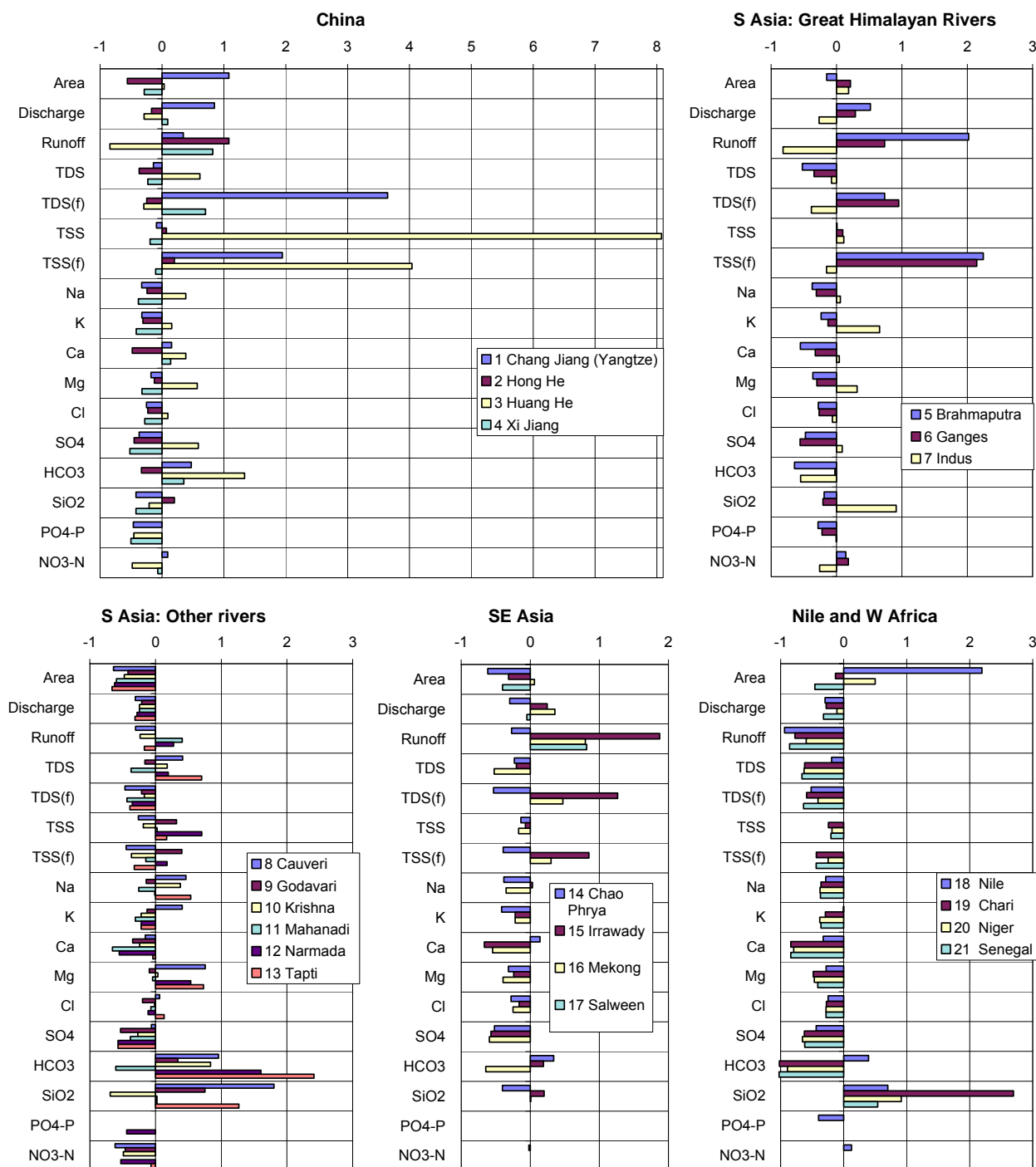


Table 6.3e

Results of GIWA with respect to the areas that fall in the study regions (GIWA 2003)

<div> Legends <div> <div>No impact</div> <div>Slight impact</div> <div>Moderate impact</div> <div>Severe impact</div> </div> </div>	Mediterranean	Yellow Sea	Bohai Sea	East-China Sea	Canary Current S	Gulf of Guinea	Lake Chad	Arabian Sea	Bay of Bengal	South China Sea	Mekong River	Sulu-Celebes Sea	Indon. Sea, Sunda
I Freshwater shortage													
- Modification of stream flow													
- Pollution of existing supplies													
- Changes in the water table													
- Economic impacts													
- Health impacts													
- Other social and community impacts													
II Pollution													
- Microbiological													
- Eutrophication													
- Chemical													
- Suspended solids													
- Solid wastes													
- Thermal													
- Radionucleides													
- Spills													
- Economic impacts													
- Health impacts													
- Other social and community impacts													
III Habitat & community modification													
- Loss of ecosystems or ecotones													
- Modification of ecosystems or ecotones													
- Economic impacts													
- Health impacts													
- Other social and community impacts													
IV Unsust. exploitation of Fisheries													
- Overexploitation of fisheries													
- Excessive bycatch and discards													
- Destructive fishing practices													
- Decreased viability of stocks													
- Impact on biological & genetic diversity													
- Economic impacts													
- Health impacts													
- Other social and community impacts													
V Global change													
- Changes in hydrological cycle													
- Sea level change													
- Increased UV-B radiation													
- Changes in ocean CO ₂ source/sink													
- Economic impacts													
- Health impacts													
- Other social and community impacts													
Coverage of the five study regions (+ indicates that also other areas are included)	Nile Basin +	Central China (Yangze etc.)	North China Plain	SE China	Mauritania, Senegal, Gambia +	W Africa exc. Canary & Chad +	Chad Basin	Pakistan, W India +	E India, Bangladesh +	Vietnam, S China, Philippines +	Mekong Basin	Parts of Indonesia	Parts of Indonesia

Box 6.3b

Environmental vicious circles

An example of lake eutrophication.

Environmental problems—such as deterioration of surface water quality—are often complex consequences of mutually connected processes that perpetuate one another. Such vicious circles tend to be difficult and costly to break, once they are in full force (Varis 1999). Many environmental vicious circles are known well enough in theory. However, over and over again, such circles are set in full speed instead of preventing them beforehand.

Prevention of environmental vicious circles would, though, be in most cases a far more economic option in the long run than the other alternative: letting the problems grow visible, and acting only with a considerable lag after that—a lag that seems to be necessary for political argumentation.

At present, one of the slogans in emerging economies is *first pollute, then clean* (Figure 6.3e). The argumentation goes in the following way: “...now there is no money to take care of environmental pollution. We have to put all the efforts to build up the economy. Once the money is there, the time is right for environmental investments”.

It has been shown too many times, that such solutions become extremely expensive, once the damages have been done, and the vicious circles keep on running although the external conditions have been improved by environmental investments.

One of the myriad of such vicious circles, or actually a pair of circles, is related to the eutrophication process of a lake. External nutrient loading, particularly phosphorus (P) and nitrogen (N), enhances the growth of phytoplankton and macroplants. This causes increased consumption of dissolved oxygen, due to degradation of more and more organic material. In oxygen-poor conditions, P plus many other harmful substances are mobilized from the bottom sediments and they, in turn, further boost primary production.

In parallel, increased nutrient concentrations favor the growth of bluegreen algae (known also as Cyanobacteria), which are able to fix N from the atmosphere to the ecosystem. This fertilizes the lake further, and enhances the growth of primary producers. Many bluegreen algae strains are toxic, being therefore very harmful to almost all uses of water.

Breaking these vicious circles has been found highly expensive in innumerable cases in Europe, North America and increasingly in other continents as well. Despite of that, the investments to wastewater treatment, diffuse pollution control, industrial waste management, etc., tend to come too late. The political will is evidently difficult to raise before the problems emerge visible. In that instant, the vicious circles are already in place.

Figure 6.3e

Pollution first then clean policy often creates vicious circles that are difficult to cut later

Left: The first pollute—then clean philosophy tends to produce problems, which became much more expensive to solve afterwards than prevent beforehand. Right: Once the vicious circles are there, the removal of external load is no longer enough when restoring the ecosystem. The vicious circles must be broken. This tends to be difficult and, in many cases, has proven extremely expensive.

