IRON FLUX BEHAVIOR ANOMALY IN THE AMUR BASIN IN 1990S: FEASIBLE REASONS

SHAMOV V. V.[1, 2], ONISHI T.[2], AND KULAKOV V. V. [1]

[1] *Institute for Water and Ecological Problems FEB RAS, Khabarovsk, Russia*

[2] *Research Institute for Humanity and Nature, Kyoto, Japan*

ABSTRACT

The abrupt increase of the iron flux in the Amur nearby Khabarovsk in 1996-1998 is discussed. It was concluded about principally climate cause of such behavior of iron.

Key words: *Amur, swamps, iron, climate change, organic matter, surface water, underground water*

The long-term monitoring of surface waters in the Amur River basin by Russia State Hydrometeorological Service has revealed a splash increase (by 3-4 times) of the total and dissolved iron flux at Khabarovsk in the last decade of XX.

The content of the different forms of iron in natural waters is to be a subject of several aspects of study. For instance, from the point of water-supply view, high concentration of this widespread biogenic compound deteriorates water quality and requires for special water treatment technology. On another hand, from the point of view of that iron takes part in biotic cycle, its high inflow in sea with the river flux provides high biological productivity of marine ecosystems [1]. There already revealed that share of dissolved Fe form in the Lower Amur Region waters is to be 40-70 % of the total Fe, and in the Amur tributaries – 30-40 %, and, meanwhile, the rivers with highly swamped valleys have water with sufficiently prevailing share of dissolved Fe [2; 3].

Hydrological and geochemical studies in the Amur basin give a possibility to make a believable basis to deduce the mechanism of Fe migration behavior in the Middle and Lower Amur.

Due to extremely vast area (almost 2,000,000 km^2) the Amur basin consists of some different landscape-geochemical provinces being drained by underground and river networks that differ by Fe concentration. The main sources of Fe in underground and river waters are considered to be the soil and rock minerals which include Fe and spread in major throughout of the northern taiga part of the Amur basin [4; 5] (fig. 1). High mobility of Fe within the Amur basin is caused by formation of acid (fulvic) humus in mountain-taiga soils and peat soils, and enleaching from minerals and migration of Fe occur with supracolloidal soil and rock particles as well as with suspensions [6; 2]. “Organic” Fe (Fe-organic compounds) appears as the prevailing share of dissolved Fe in the Amur tributaries water within the Amur floodplain expansions [3].

The regular over-saturation of soils within between-mountain depressions makes the favorable environments for generation of fluent Fe compounds. The combination of over-watering and atmospheric precipitation infiltration determine together the migration of these compounds as along the soil profile as to the deeper groundwater, in that number with the pore dissolutions of hard-permeable clay bodies. Within artesian basins of the Russia South Far East, there were found out the significant increase of divalent (protoxidic) Fe contents in ground and pressure-ground water downhill [4]. Divalent Fe contents in soil-ground water beneath peat layer was found to vary in limits of 20-60 mg/dm^3, and swamping (peat layer accumulation process) rate determines as a whole the divalent Fe increase rate in underground water on the Middle-Amur / Sanjiang Plain [7].

Peat-ground water, enriched by humic acids, seems to provide just small share of Fe content in water of by-pass streams. This is due to negligible role of swamp water in the runoff generation in Amur and its tributaries during warm period (in winter almost all swamps freeze through mineral bottom and deeper). For instance, according to I. Meshchenin's estimates [8], annual runoff generated from vast swamps of the Middle-Amur Plain (they occupy totally about 13,000 km^2), is estimated to be 228 mm/y, or 94 m^3/s. This value, thus, consists less 1 % of the total annual runoff value in Amur nearby Komsomol'sk-na-Amure (the lower end of the vast Middle-Amur / Sanjiang Plain). Very often siccation of swamps and mares on the Amur plains in warm period – June-October – allows to conclude that they generate runoff actually when 1) spring thaw occurs contemporarily with seasonal frost presence, and 2) during hard summer-autumn monsoon rainfalls occur that conduces to fast over-watering of the predominantly thin (less than 1 m) peat layer of those swamps. We have to take into account, also, that prevailing part of wetlands stretches within the Amur valley bottom downstream Khabarovsk-city, and the "upstream" wetlands is mainly agriculturally developed, especially within Heilongjiang Province of China as well as in Russian part of Khanka Lake valley, and actually have lost the natural peat- humus stock to-date.

A negligible role of peat swamps as sources of Fe in the Amur water seems to be confirmed by special expedition research in August 2006. As the result, there was found the excess of dissolved Fe income to Amur by 2.0-2.5 times within mountainous gorges of its valley in comparison with its floodplain expansions [9]. Few small streams, which watersheds are located totally or almost totally within boggy accumulative plains, are to be considered in this relation as an exception, but not a rule [3].

While we recognize that underground water, drained by the Amur tributaries' headwaters, makes a significant share of their runoff [10; 11], we are to consider the soils of mountain-taiga landscapes to be the main source of Fe in the Lower Amur's water.

The dam control of Upper Zeya has mitigated the amplitude of total Fe contents dynamics, thus, in 1988 the amplitude has been observed to be 0.12-0.47 mg/dm^3 downstream the dam [12]. The increased values of Fe contents (in 1988 – 0.52-1.86 mg/dm^3, in 1994 – up to 1.15 mg/dm^3) were observed just in bottom water layers in Zeya reservoir nearby dam and were related by mentioned researchers to the reduction anaerobic ambience in this deepest part of the reservoir. Totally, it was marked a decrease and stabilization of Fe contents level in Zeya reservoir since 1978 till 1994.

Since Zeya Reservoir start-up (1975) the share of Zeya in the Amur winter flux has been steady rising. Analysis of observation data series, obtained by Far East Department of Russia State Hydrometeorological Service, demonstrates the up-trend of winter discharges in the Lower Amur since early 1980's by nearly 2 times as well as the dissolved iron contents and flux splash increase in the Lower Amur water in 1996-1998 (fig. 2-5).

Figure 3 shows steady low winter flow of Fe in the second half of 1990's, meanwhile, the winter Fe concentrations in the Amur water in 1996 and 1997 look to be much higher comparing with ones in previous and further periods (fig. 3). Supposedly, risen Fe concentrations in Lower Amur in winter 1996 and 1997 could be caused by high Fe concentration in the Zeya water that has been feeding the Amur River.

Some researchers wrote about a sharp rise of near-surface air temperature recorded by array of meteorological observation stations in the Amur Basin, both in Russia and China [13; 14]. Particularly, a deviation of average annual air temperature in 1989, 1990 and 1995, according to [13], reached and exceeded a value +1.5 ºC relative to mean temperature in basic period 1960-1990. Besides warming, in 1990's there were marked the increase of average annual precipitation sum over the Amur basin as a whole: in 1991 and 1992 – by more than 10 %, in 1995 – by 20 % in comparison with basic mean values estimated for period 1960-1990 [13]. In Trans-Baikal Region (Bakal Lake basin and the Amur headwaters) a sharp increase of annual precipitation sum has been registered in 1995 as well [15].

Comparatively sharp increase of air temperature in the Amur basin totally, and in its northern part especially, is to create the beginning (acceleration?) of the permafrost degradation – both laterally (regression of permafrost boundary to the North) and in aspect of its thickness. The permafrost zone diminishing as well as its transformation somewhere to seasonal one have been providing the infiltration of additional quantity of soil water enriched by Fe into underground water which was to income into mountain streams several years later (2-12 years, according to review in [11]).

By data obtained in Amurskiy Territorial Center of Hydrometeorology in Blagoveshchensk, mean annual air temperature, registered in meteorological stations within the Zeya basin and adjacent river basins in 1996 (see area at fig. 1), was either close to the norm or exceeded it by 1.0-1.5 ºC. At the same time, winter in 1996 as well as winter in 1995 was warmer than norm by 2-3 ºC. Spring and summer in 1996 were warmer and drier than usual ones, and autumn – rather warm and durable one.

The average annual temperature in 1997 within northern part of the Amur basin exceeded the climatic norm by 1.5-3 ºC. This excess was provided by moderately warm winter, early warm (by 2-5 ºC higher than usual one) spring and long warm summer. Winter precipitation amount in that year was recorded to be 130-200 % of the norm.

1998 in considered territory was in average warmer than a norm by 1-2 ºC, thereby increased temperature background has been prevailing along a whole year, and mean winter temperature exceeded a norm by 2-4 ºC. Summer in mountain and piedmont areas of the territory was long and warmer than common one by 1 ºC, and in June-July the precipitation amount was recorded to exceed the mean value by 1.3-1.8 times, and in the Amur headwaters – by more than twice.

In the table below one can see some data about year-by-year dynamics of total Fe in water of the northern rivers of the Amur basin. These data speak about sharp increase of this element concentration by 2-3 times in 1996-1997, with that, the annual volume of sewage greatly contaminated by heavy metals, over given territory fallen from 0.678 to 0.567 m^3/s.

The fact that for some northern rivers (Tynda, Selemdzha, Bol'shaya Pera and Bureya) the Fe concentration peak has delayed for approximately 1 year (1997) in comparison with Amur and Zeya, – that fact points to the most likely "permafrost" origin of Fe contents splash anomaly.

After 1998 Fe flux in Amur nearby Khabarovsk has fallen again to $1.0\text{-}1.5 \cdot 10^5$ ton per year, while Fe concentration in the Upper and Middle Amur water has been staying higher than in 1995 at average (see table).

This Fe flux decrease, obviously, is caused by sufficient precipitation rate decrease over the Amur basin. Thus, according to studies by P. Novorotsky [13], already in 1997 annual precipitation amount over the entire basin was observed as less than 90 % of the norm, and in 2002 – less than 80 % of the mean value. Meantime, in 1998, a powerful rainfall flood occurred on the biggest Middle Amur tributaries. Totally, during the last 15 years (1991-2006) there found a smoothed steady decline trend of annual precipitation amount. Particularly, in 2001-2004 average annual values has hardly exceeded 90 % of the norm, and average annual total runoff of Amur through the same period appeared to be less by 20 % the mean value estimated for 1891-2004. Markedly, significant linear decline trends of precipitation amounts of cold period for the last 30 years were revealed in the Upper Amur basin [13].

CONCLUSION

Thus, 2 main sources of Fe income to the main rivers of the Amur Basin are to be taken into account:

1) Soils and rocks of mountain areas – commonly headwaters – where river flow is generated mainly by underground water;

2) Swamps on the vast Amur plains where some water highly enriched by Fe sometimes are drained by undeveloped network of small plain streams and quite large bypass ones.

The main reason of abrupt rise of Fe flux registered in the Amur basin in 1990's appears to be climate change – increase of air temperature and precipitation rate. The latter leads to permafrost degradation in its near-southern-edge areas and, therefore, to increased permeability of melted soils and underlying grounds. Moreover, the warmer atmospheric precipitation infiltrated into deeper underground layers, supposedly, is to accelerate the physical-chemical processes of resorption of minerals and the dissolved Fe flush-out from soils and rocks. The role of plant-soil cover on the vast area submerged by Zeya Reservoir in 1970s, in Fe flux rise in 1990's does not tracked up distinctly.

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Figures

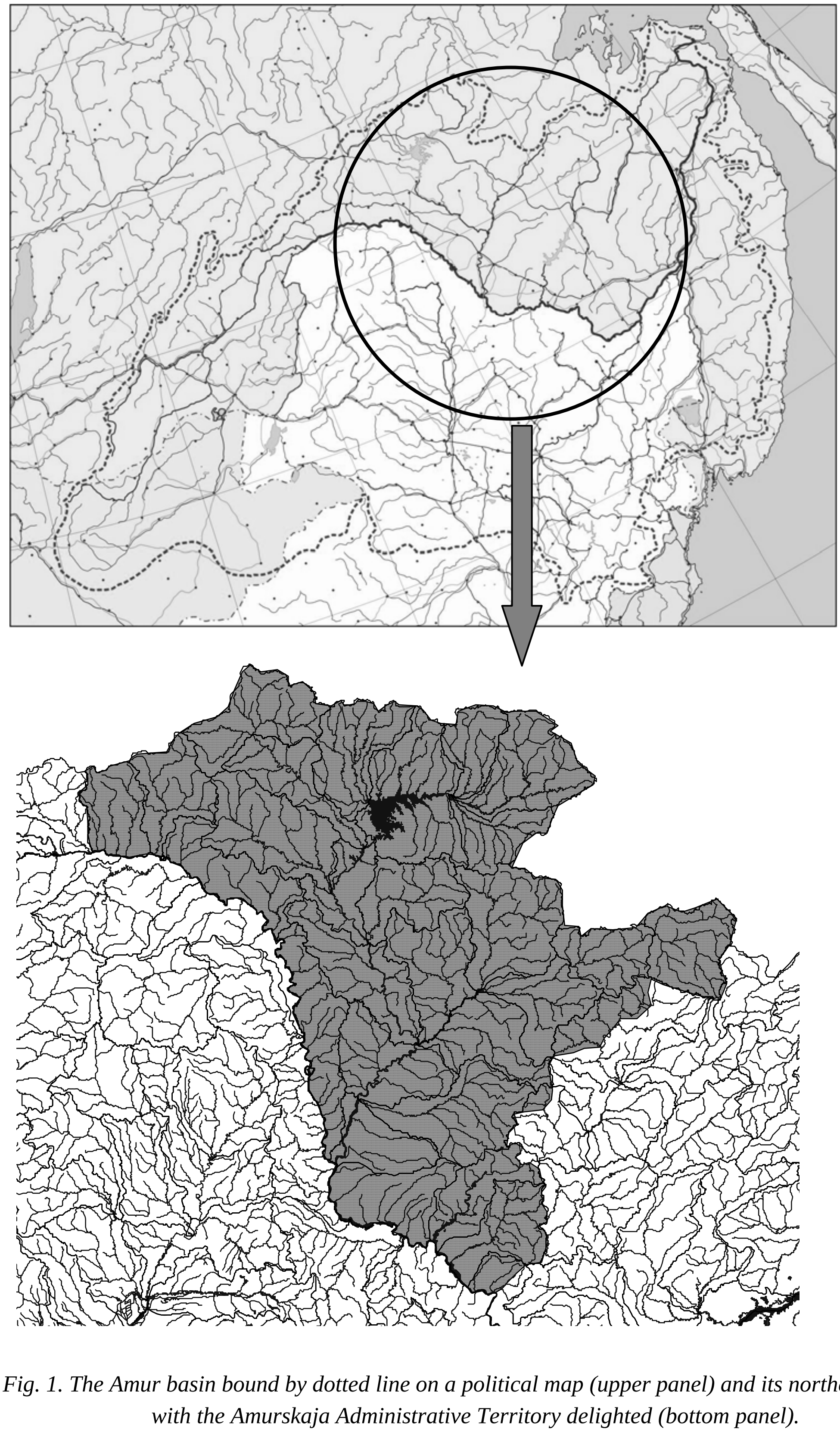

Fig. 1. The Amur basin bound by dotted line on a political map (upper panel) and its northern part in detail with the Amurskaja Administrative Territory delighted (bottom panel).

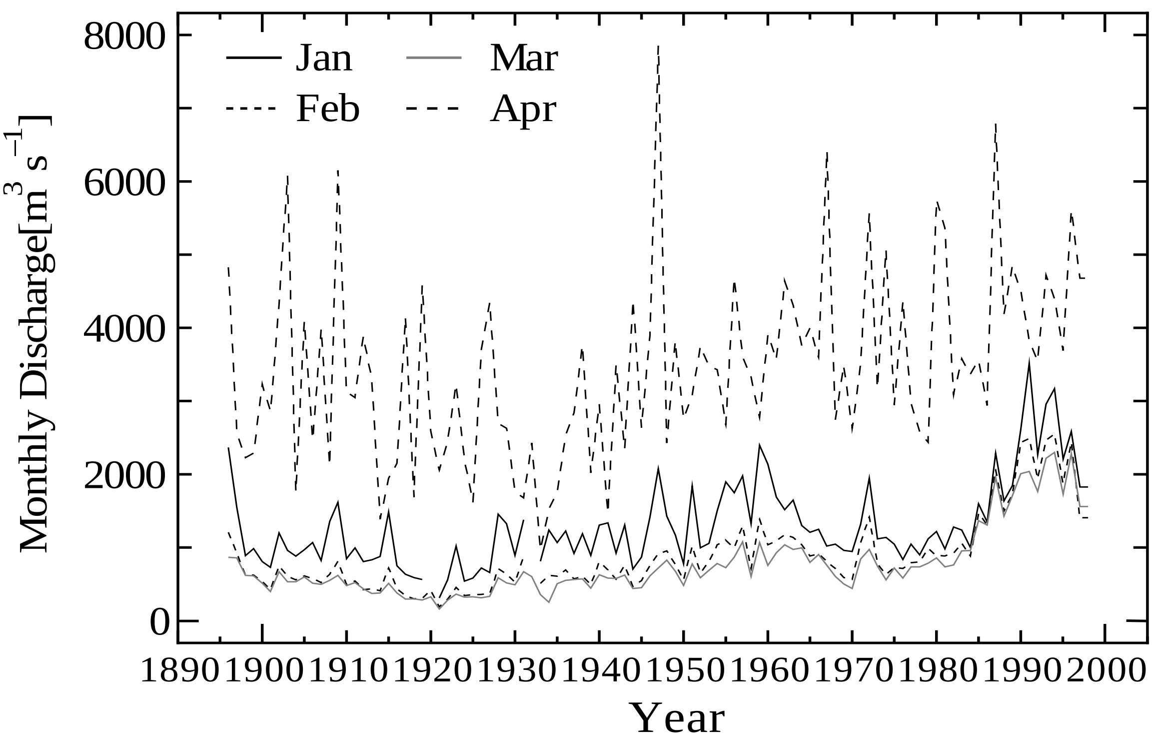

Fig. 1. Dynamics of average cold month discharges in the Amur nearby Khabarovsk. 1896-1999. Numbers at lines correspond to month since November (1) to April (6).

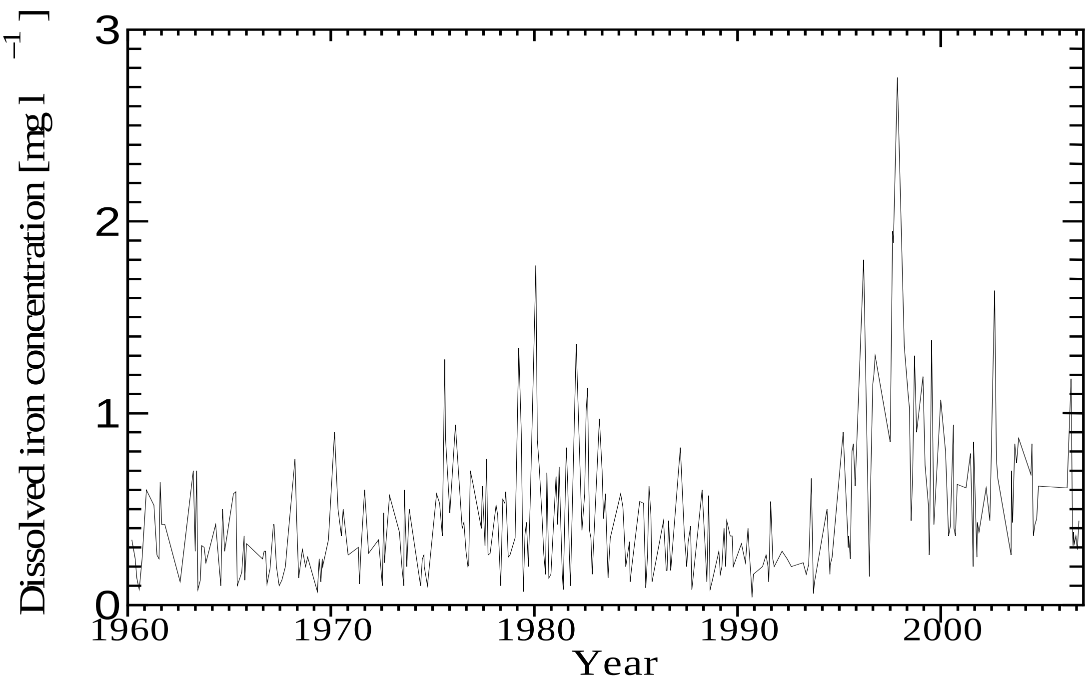

Fig. 2. Dynamics of dissolved Fe concentration monthly measured in the Amur water nearby Khabarovsk. 1960-2006.

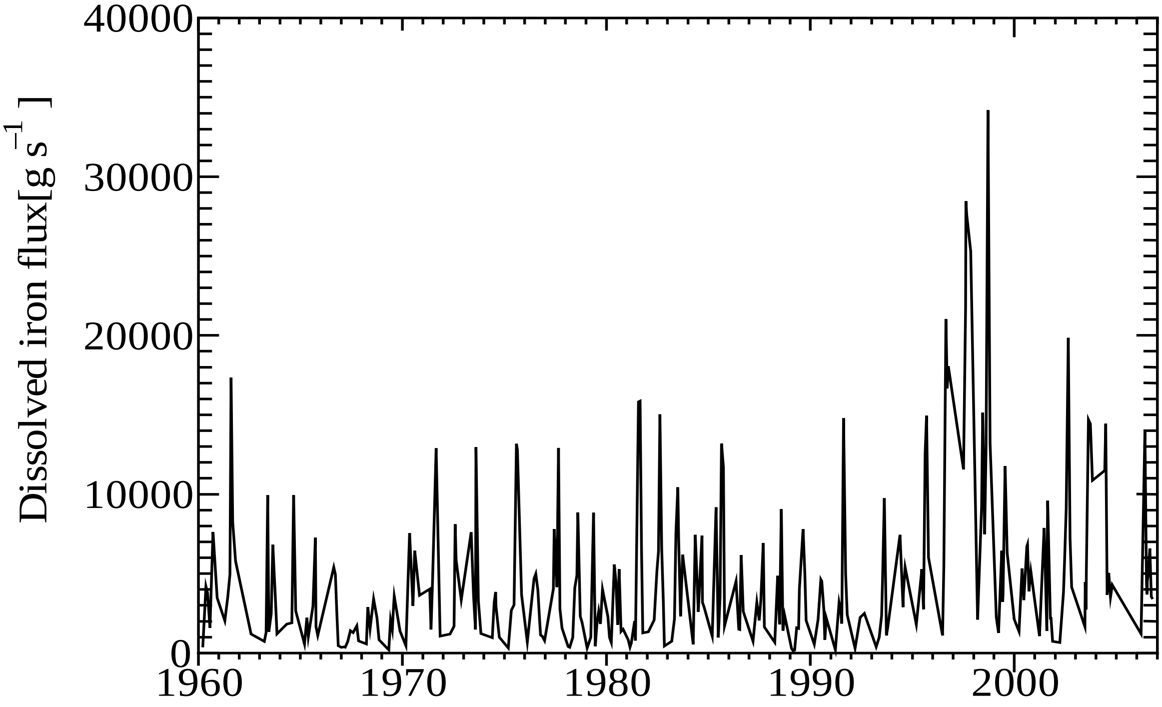

Fig. 3. Daily average discharges of dissolved Fe in the Amur nearby Khabarovsk. 1960-2005.

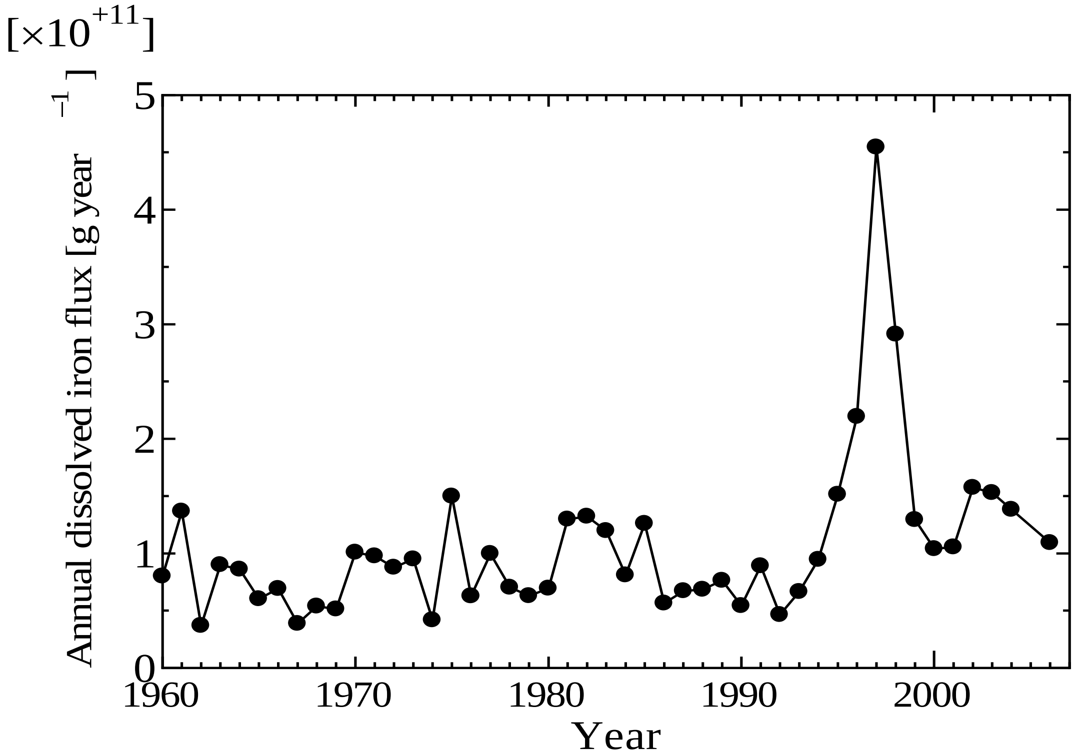

Fig. 4. Behavior of annual dissolved Fe flux in the Amur nearby Khabarovsk. 1960-2006.

Table

Average total Fe contents (mg/dm^3) in the river water within northern part of the Amur Basin

River – site of observation	1995	1996	1997	1998	1999	2000
Amur – Blagoveshchensk (1 km upstream city)	0,20	1,39	1,11	0,53	0,56	0,49
Amur – Blagoveshchensk (5 km downstream Zeya mouth)	0,28	2,35	2,25	1,80	0,91	0,70
Zeya – Blagoveshchensk (1 km upstream city)	0,43	1,17	0,90	0,41	0,83	0,77
Tynda – Tynda (1 km upstream town)	0,27	0,51	1,17	0,55	0,83	0,35
Bol'shaya Pera – Shimanovsk (0,5 km upstream town)	0,66	2,47	2,65	1,29	1,36	1,24
Tom' – Belogorsk (1 km upstream town)	1,13	1,49	1,31	0,96	1,14	1,15
Bureya – Novobureysk (1 km upstream town)	0,67	0,91	1,16	0,79	0,73	0,79
Selemdzha – upstream mouth	0,54	0,34	1,30	0,81	no data	no data