Interannual variations and decrease of the river runoff in the Lake Balkhash basin, in Central Asia

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ABSTRACT

The Interannual variations and decrease of river runoff draining into the lake Balkhash basin, in Central Asia are investigated by using meteorological and hydrological data over long term period.

At first, it is found that an apparent increase of decrease trend is not seen in the interannual variability of the meteorological elements in the basin. Next, interannual variations of the annual mean runoff in the rivers are investigated by the difference integral curves. From this analysis, it is determined that a low flow period begins in 1970 in the Ili-river and in 1973 in the eastern rivers, respectively.

Finally, the Characteristics of the integral curves of runoff in the runoff growing season (from Apr. to Sep.) and non-growing season (from Oct. to Mar.) of entire period are investigated concerning the 3 sections of the upper, middle and lower reach of the Ili-river .The following results are obtained. (1) The mean runoff of the non-growing season at the 3 section has remained virtually unchanged entire period.(2) The largest decrease of runoff growing period of the Ili-river has occurred in the middle and lower reaches, respectively. These amounting to 44%, 45%of mean runoff of the growing season before 1969,respectively. Also the effect of human activity is responsible for 58%, 60%, respectively.

This study has quantitatively made clear that the main reason of the apparent decrease of the runoff of the Ili-river is derived from the human activity.

INTRODUCTION

The Lake Balkhash basin is one of the largest internal drainage located in the arid and semi-arid region of in Central Asia. It covers 413,000 km^2 between 73° 20´ E and 79° 10´ E and 45° 00´ N and 46° 44´ N. 85%and 15% of drainage are in the republic of Kazahkstan and in P. R. China, respectively.

The major rivers draining into the lake Balkhash basin are Ili, Karatal, Aksu, Lepcy and Ayaguz (Fig.1). The latter four are draining from east part of the Lake , which are referred to as east rivers in this study. These rivers are originated from the Khrebet Dzhungarskiy Alatau mountains located in the north-east part of the basin and from the Tien- Shan mountains located in the south-east part of the basin (Fig.1).The lowland parts of the basins of these rivers are regions of runoff utilization or dissipation because of losses through evaporation and infiltration into the soil.

According to the investigations of Sidhikov J.S et al.,(1992) and Kader et al.(1996),the surface water resources of the east rivers are estimated at 6.4 km^3 /year and of the Ili-river is estimated at

17.4 km^3 /year, respectively. The latter accounts for the 730% of the total surface inflow into the lake .The total water resources of the lake Balkhash basin in the zone of runoff formation amount to 23.8 km^3/year. Ground water inflow is not so insignificant. According to Kawabata and Tsukatani (1996), it does not exceed 0.1-0.3% of the surface water resources.

Water resources are mainly used for the irrigation, industry, water supply to populated areas, and the fishing industry. According to Fukushima(1993) ,the interannual variability of the increase of irrigated areas in the last 20 years are estimated as follow.

Table.1

Year	1965	1970	1975	1980	1984
Irrigated areas (km^2)	3639	4288	4638	5259	5596

By analysis of the precipitation, surface inflow into the lake, and water level of the lake in the period before 1969, Kudrin and Rubinovich(1976) and Zhirkevich (1972) came to the conclusion that despite the development of irrigation and other types of water use in the basin in this century, the observed hydrologic series for 1969 can be taken as the natural conditions in the first approximation. The filling of the Kapchagay reservoir in 1970 produced a drastic change of the natural regime of the Ili-river and Lake Balkhash (Kudrin R.D et al.,1976; Sidhikov .J. S et al., 1992;Yang and Chao,1993).Before 1970,the fluctuations of the hydrologic budget and level of the lake were mainly determined by climatic factors (e.g., precipitation and temperature)as well as by the change of losses of water in the Ili-river delta which is associated with the development of its channel network (Kudrin, R.D et al.,1976). Because of the observed low flow, the over- development of irrigation, and the construction of the Kapchagay reservoir, the changes in the runoff of the Ili-river have become more pronounced and have led to a drop in the level of the Lake Balkhash by approximately 2.66 m since 1970.

Several previous studies devoted to water level fluctuations, water balance of the lake Balkhash, forecast of the change in the hydrologic budget using climatic and runoff data on the middle or lower reach of the Ili-river. However, there are few studies which investigated the interannual variation of annual /monthly runoff at the various gagging stations in the zone of runoff formation and in the zone of use of water resources in the basin, especially related variation of the runoff during the growing season (from Apr. to Sep.) or non-growing season (from Oct. to Mar.).

The purpose of the present paper is to analyze precipitation, air temperature and hydrologic data in the Lake Balkhash basin. Especially, the investigation refers to various gagging stations in the upper, middle and lower reaches of the Ili-river. Special attention is paid to the comparison among runoff in these reaches, concerning the interannual variation, annual runoff and runoff of growing season and non-growing season. The comparison is made between mean runoff over following period: (1)a natural or conditionally natural regime;(2) a modified regime of intensive development of irrigation.

DATA and METHOD

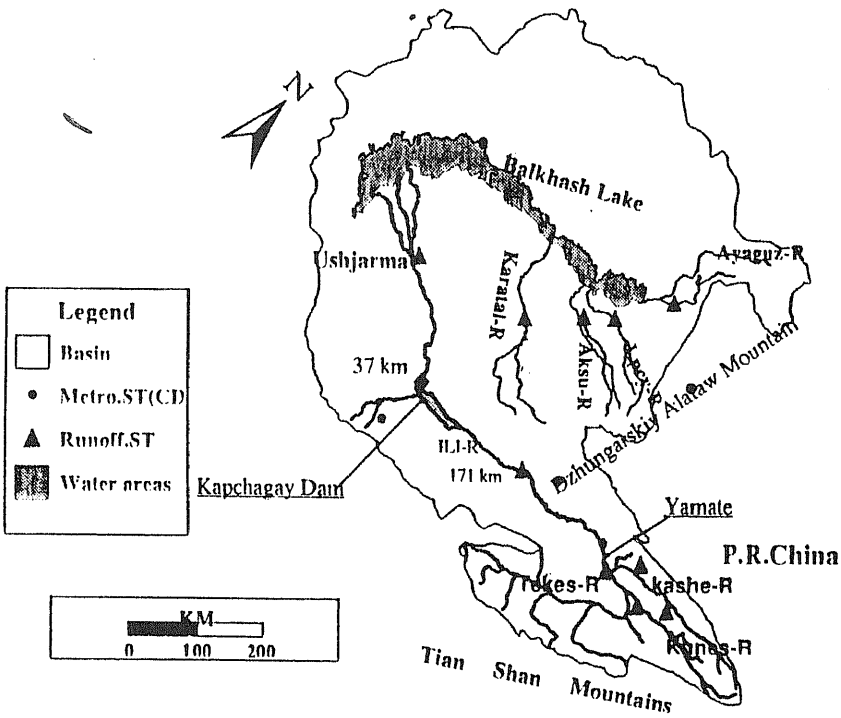

Fig.1 Map of Lake Balkhash basin in Central Asia, created by the Topographic map (scale;1: 5000,000)produced by the defense Mapping Agency Aerospace center in USA.

The long-term annual/monthly precipitation and air temperature are calculated with the data of GHCN(Global Historical Climtology Network) of CDIAC(Carbon Dioxide Information Analysis Center) in USA along with the data of RIHMI-WDC (Research Institute of Hydro-meteorological Information-World Data Center) in Former USSR.

In addition ,the following river discharge data are used in this study :

- Annual/monthly runoff data of the 171 km,37 km and Ushjarma gagging stations located in the upper and lower reaches of the Kapchagay reservoir and the delta of the Ili-river are available during 1966—1992,1911—1986,1949—1986 , respectively . Also, annual/monthly runoff data of the Karatal, Aksu, Lepcy and Ayaguz rivers are available from 1924 to 1986.These data are provided by Drs. J.Dostayev and A.A. Tursunov of Institute of geography, Kazahkstan Academy of Sciences).
- Annual/monthly runoff data of the Tekes, Kunes and Kashe rivers of the upper reach of the Ili-river and the Yamate gagging station in the Ili-river are observed about from 1954 to 1990 by Xinjiang general hydrometric station in China.

The relationship between runoff data at the Yamate and 37km gagging station of the Ili-river (Fig. 1) from 1954 to 1969 is investigated to reconstruct the data series of the annual discharge of the Yamate from 1911 to1954. The correlation coefficients R and standard error δ , of are estimated to be 0.95 , ± 23.1 m^3/sec,respectively. The regression equation ($Q_y=0668Q_{37}+71.9$) is defined.

In order to analyze interannual variation of annual mean precipitation and air temperature in the basin for the entire observation period. The data series are reconstructed using the equation below:

$$K=(X-x)/SDT \qquad (1)$$

Where K is the normalized value, SDT is standard deviation, X and x is the annual mean of the each year and the average of the entire observation period data, respectively.

For evaluating the interannual variation and decrease of the mean runoff of the rivers, difference integral runoff curves and integral curves of runoff depth are calculated, respectively, with the following equation:

$$F(t)= \Sigma[(K_t-1)/Cv] \qquad (2)$$

Where F (t) is the difference integral runoff curves with time(t) , $K_t = Q / q$;here Q and q is annual mean runoff data(m^3/sec) ,and the average of the entire observation period annual mean runoff ; Cv is coefficient of the variation.

$$G(t)=\Sigma H=\Sigma Q/A \qquad (3)$$

$$W=(\Sigma H_o - \Sigma h)*A*10^{-6} \qquad (4)$$

Were G(t) is the integral curves of runoff depth with time(t); A is area of the watershed(km^2); H is mean runoff depth for the study period (mm) ; W is total decrease value of mean runoff for the study period(km^3); H_o is calculated value of the runoff depth(mm)after1969 by applying the extend line of regression equation of the Fig.5-7(b) ,which is considered as nearly natural condition before1969; h is the runoff depth(mm) observed value after 1969 .

RESULTS and DISCUSSION

In order to discern whether there is some trends in climatic conditions in the basin, the interannual variability are investigated over long-term period. Figure.2 (a) and 2(b) shows interannual variations of the normalized annual mean air temperature (K_t) and precipitation (Kp) for four meteorological stations in the basin. The apparent trends are not found in both temperature and precipitation time series, with the exception of annual mean the precipitation at the Balkhash city in 1976.

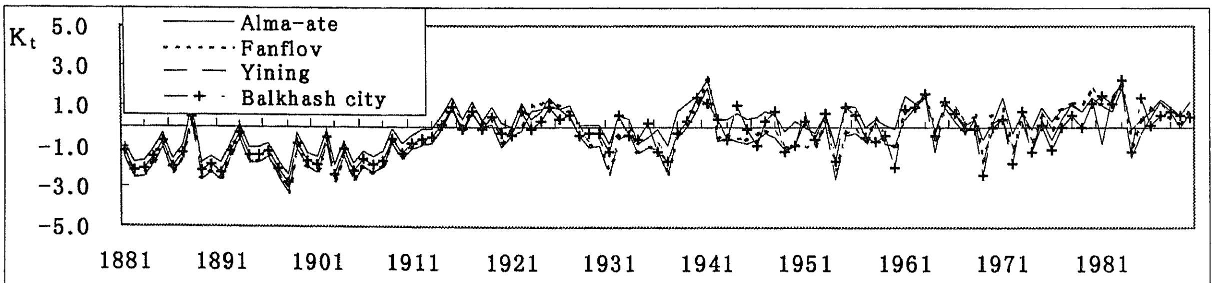

Fig .2 (a) The interannual variation of normalized annual mean air temperature (Kt) at the Balkhash city ,Alma-ate ,Fanflov and Yining meteorological station located in the Balkhash lake basin

Difference integral runoff curves in the Fig. 3 shows respectively the interannual fluctuations of the annual mean runoff in the upper and lower reaches of the Ili-river from 1911 to 1990. Also, Fig. 4 shows that of the zone of runoff formation of the Karatal, Aksu, Lepcy and Ayaguz rivers during

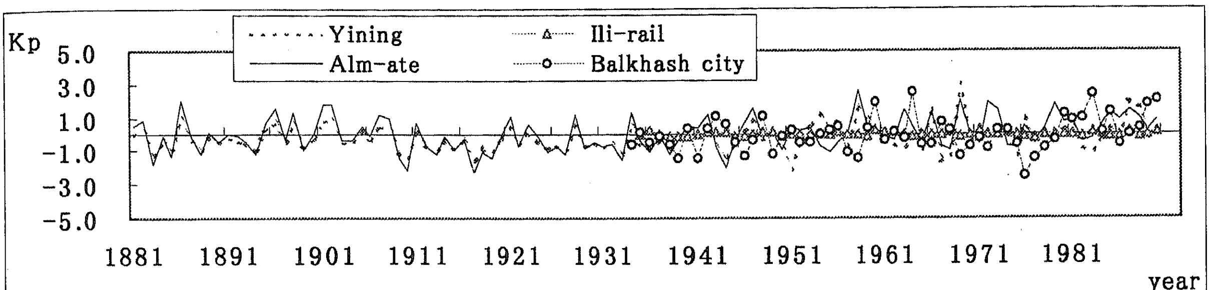

Fig .2(b) The interannual variation of normalized annual mean precipitation (Kp) at the Balkhash city, Alma-ate ,Ili-rail and Yining meteorological station located in the Balkhash lake basin

the entire observation period. Figure.3 and .4 illustrates that a low flow period begins in 1970 in the Ili-river and in 1973 in the east rivers, respectively. These low flow periods are responsible for the variation of the total runoff in the basin. In Fig. 3, we can see that the range of the decrease in annual runoff of the 37km gagging station, located lower reach of the Kapchagay reservoir in the Ili-river, is a sharper than 171Km or Yamate gagging station after 1970.

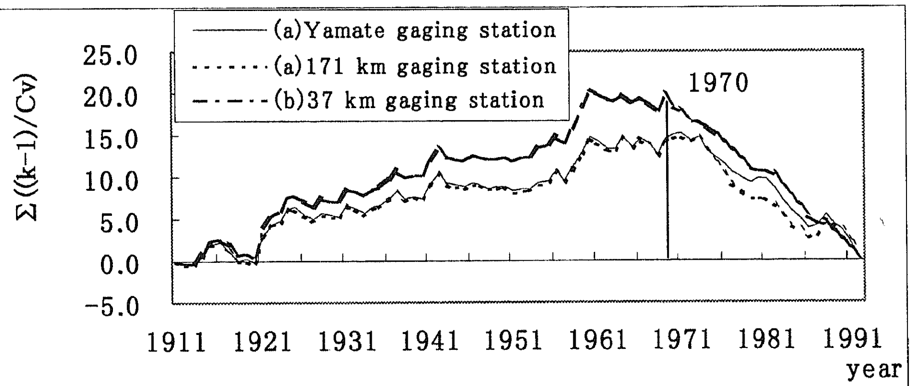

Fig.3 Difference integral curves of the annual mean runoff in the upper reach (a) and middle reach (b) of the Ili-river from 1911 to 1990.

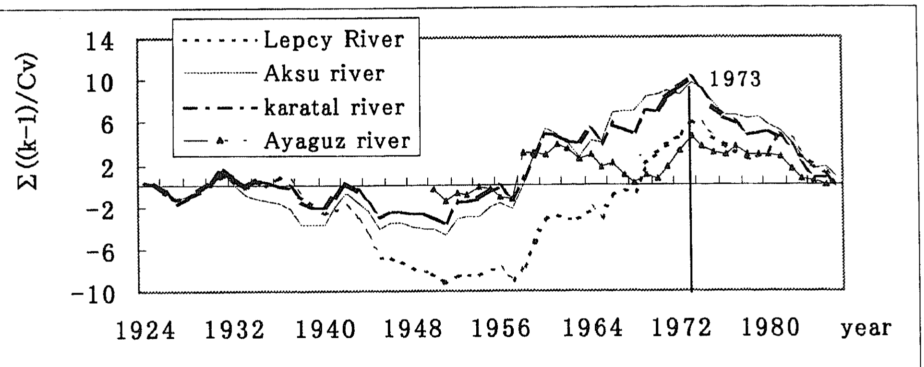

Fig.4 Difference integral curves of the annual mean runoff in the Lepcy ,Aksu , Karatal and Ayaguz rivers from 1924 to1986.

By comparing the average runoff before 1973 and 1970,respectively, the decrease of the annual mean runoff in the karatal, Aksu, Lepcy and Ayaguz rivers for from 1973 to 1986 are respectively 20.2 m^3/sec, 1.7 m^3/sec, 2.3 m^3/sec and 5.0 m^3/sec. As for Yamate gagging station in the Ili-river from1970 to 1990, the decrease of the annual mean runoff is 59.7 m^3/sec.

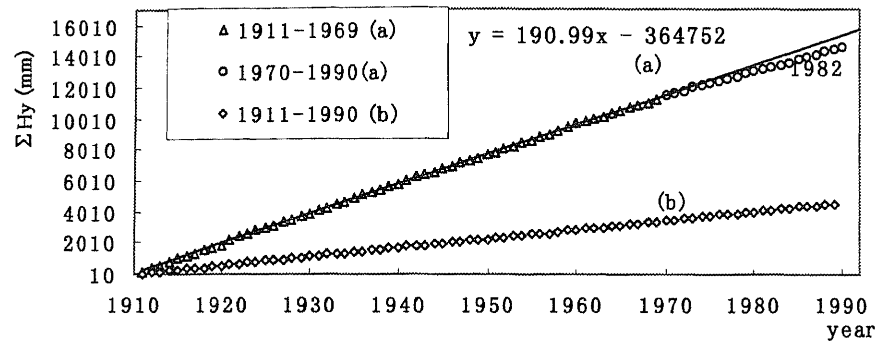

Fig.5 Integral curves of the mean runoff depth in the growing season(a) and non-growing season(b) at the Yamate gagging station located in the upper reach of the Ili-river from 1911 to 1990.

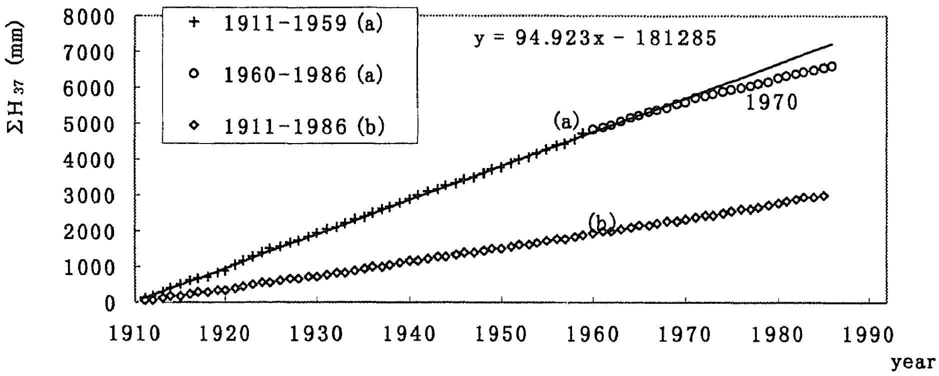

Fig.6 Integral curves of the mean runoff depth in the growing season(a) and non-growing season (b) at the 37 km gagging station located lower reach of the kapchagay reservoir in the Ili-river from 1911 to 1986.

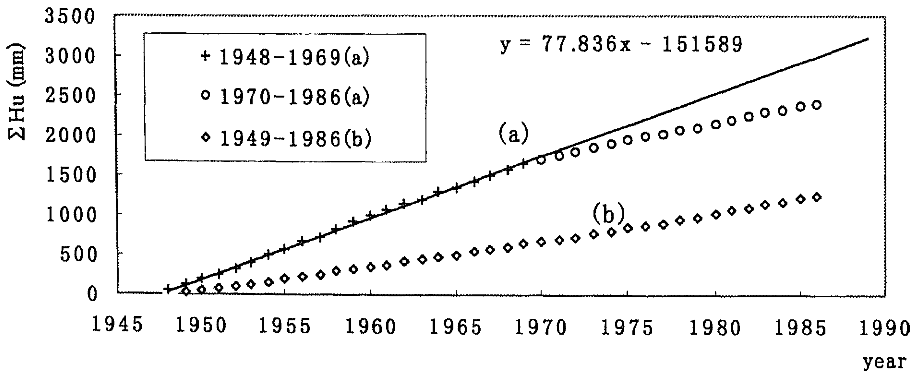

Fig.7 Integral curves of the mean runoff depth in the growing season (a) and non-growing season (b) at the Ushjarma gaging station located in the delta of the Ili-river from 1948 to1986.

In order to discern the effect of the development of irrigation including the filling of the

Kapchagay reservoir, and natural variability, the integral curves of the runoff depth (ΣH) is calculated based on Eq.(3). This equation is applied for both the runoff growing season and non-growing season at Yamate gagging station, at the 37 km gagging station in the lower reach of Kapchagay reservoir and at the Ushjarma gagging station located in the delta of the Ili-river. These results are presented in Figs .5 –7, respectively. It should be remembered that the integral curves on runoff depth(ΣH) of these figures represent the combine effect of natural condition and human activity, which are related to the variability of mean runoff in the 3 sections of the upper, middle and lower reaches of the Ili-river.

Before analysis the Fig.5-7, it should be noted that the observed data series of the Yamate from 1954 to 1990 is taken into account in constructing the relationship between annual mean runoff at the Yamate and (ΣQ)sum of annual mean runoff at the reference gagging for Kashe, Tekes and Kunes rivers in the upper reach of the Ili-river. This correlation coefficient is 0.97 (significant level 5%). Therefore, it is evident that the mean runoff fluctuations at Yamate may be considered as nearly nature condition although there are somewhat under influences of the human activity.

The integral curves of Fig. 5 (b), Fig. 6(b) and Fig. 7(b) show that the distribution point of the mean runoff depth of non-growing period is approximation to corresponds to a straight line. It is also made clear that the mean runoff of the non-growing season at the 3 section of upper, middle and lower reaches of the Ili-river has remained virtually unchanged before 1969 or after that.

The integral curves of Figs.5 (a), 6 (a) and 7(a) represents that the distribution point of the mean runoff depth of growing period before 1969 approximately corresponds to a straight line. After 1970,however, these figures show that the points are fairly deviated from the line of before 1969 and show some decreasing trend. This feature is especially apparent in Fig.6 (a) and 7(a).

The results of computation of runoff decrease of the Ili-river with Eq.(4) are presented in Table.2. It is clarified that the largest decrease of runoff during growing period has occurred in the middle and lower reaches, respectively. These amounting to 44%, 45% of the mean runoff before 1969,respectively. Also the effect of human activity is responsible for 58%, 60%.

Table.2. Runoff decrease of the runoff growing season in the Ili-river (1970-1986)(km^3/yr)

Station name	Q	ΔWs	%	ΔWs	ΔWe	%
Yamate	9.4	1.9	20	1.9	0	0
37 km	10.4	4.6	44	4.6	2.7	57.7
Ushjarma	10.7	4.8	45	4.8	2.9	60.4

***ΔWs=w/n ;runoff decrease value of each year under the combine effect of the natural factors and human activity.**

***ΔWe-runoff decrease value under the human activity.(ΔWe =ΔWs –1.9),Q-mean runoff before 1969**

CONCLUSION

Based on the results and discussion of this study, following conclusions were obtained:

- An apparent increasing or decreasing trend is not found in the interannual variations of annual mean air temperature and precipitation over long-term period in the Lake Balkhash.

- The difference integral runoff curves of Fig.3 and .4 determine respectively that the low flow period begins in 1970 in the Ili-river and in 1973 in the eastern river. According to hydrometric series, the decrease of annual mean runoff from 1973 to1986 of the Karatal, Aksu, Lepcy and Ayaguz rivers are 20.2 m^3/sec, 1.7 m^3/sec, 2.3 m^3/sec and 5.0 m^3/sec respectively. It is 59.7 m^3/sec at the Yamate in the Ili-river from 1970 to 1990.
- It is made clear that the integral curves on depth of runoff (ΣH) represent the combine effect of natural condition and human activity ,which are related to be runoff variation on the 3 sections of the upper, middle and lower reaches of the Ili-river. The largest decrease of the Ili-river has occurred in the middle and lower reaches, respectively in Figs .6-7(a). These amounting to 44%, 45% of mean runoff of the growing season before 1969,respectively. Also the effect of human activity factors is responsible for 58%, 60%, respectively.
- This study has quantitatively made clear that the main reason of the apparent decrease of the Ili-river is derived from the human activity.

ACKNOWLEDGMENT

The author would like to thank Dr Matsuyama Hiroshi of Tokyo Metropolitan Univ. for his helpful advises, and thank Drs. J. Dostayev and A.A. Tursunov of Kazahkstan institute of geography and Associate Pro. Li Xin of Xinjiang institute of geography for kindness to provide the data used in this study.

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