Water shortage and its environmental impacts

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1. The analyses of water shortage

The false presumption that China has plenty of water resources may occur due to the summer flooding of many regions in 1996, and this can only be explained clearly as the result of high temporal and spatial variation of precipitation. The annual average water resource of China is about 28124×10^8 m^3, but the amount per capita is only 2400m^3, ranking in the 109th position among 149 countries according to statistical data of United Nation[1]. Thus, China, as a whole, has to face unavoidably with the water shortage problem, especially in some areas and/or in a certain period. In case of city, more than 300 cities among total 600 cities have experience the water shortage. Consequently, how to define water shortage, identify the area with such problem and assess its possible impacts on environment is becoming a more and more interesting subject among scientists and relevant organizations.

Generally, water shortage may be viewed as the occurrence of deficit in terms of water supply and water demand. Even though the water resources for supply may in the long term be stable and sustainable with regard to water circulation, water quantity available for human consumption does decline due to the deterioration of water quality. On the other hand, Chinese economy has grown about 10% annually in recent years, and the population has not yet reach its peak and about 1500×10^4 newly-born babies each year join in our family, both of these two factors require more water demand. Hence, the situation of water shortage tends to become more and more serious, which will remain in the foreseeable future.

Water shortage can also be evaluated by energy index: R/LP, where R is net radiation, L is latent heat and P is precipitation. This index is actually the ratio of potential evaporation E to precipitation, and R/L is the maximum potential evaporation. In order to subdue the effects of geomorphology, soil and et. on runoff, the amount of runoff Rs may be discounted from precipitation to obtain soil moisture influx SMI=P-Rs, and new index Ni can be defined as R/[L(P-Rs)]=R/[L*SMI]=E/SMI, which can then be used to locate the water shortage area(Liu and Du, 1985). If Ni of a given area is more than 1, this area may potentially have the problem of water shortage. This index is rather important in agriculture and regionalization.

Another index Cv, variation coefficient of annual runoff can be used to assess the water shortage, even though in an indirect way. The lower the value of Cv, the less fluctuation of runoff, and normally the more runoff and precipitation. In case of river discharge, Cv is about 0.12-0.15 for Changjiang river, 0.45 for Yellow river, 0.55-0.65 for Huaihe river and 0.60-0.75 for Haihe river. Cv for plains, basins and huge desert in north-western China is usually more than 0.8. One may defend that Cv is responding not only to the

[1] Lu Yongjian, Chinese Science News, Jan. 13, 1997

runoff itself, but also to the shape, size and other factors of the catchment, but the huge difference in annual average discharge does show the concurrence with Cv. The annual average discharge of Changjiang river is $9800x10^8$ m^3, $560x\ 10^8$ m^3 for Yellow river, $530x10^8$ m^3 for Huaihe river and only $283x10^8$ m^3 for Hailuanhe river(Zuo and Xu, 1985).

One apparent characteristic of water resources in China is its uneven distribution in time, thus resulting in seasonal water shortage. In the eastern part of China, most of rainfall precipitates in the summer, with little in the winter due to monsoon climate. The higher the latitude, the more the percentage of summer rainfall to the total yearly rainfall. Hence, the main crop, wheat, has to face with serious water shortage in the spring, when the rainfall accounts for less than 15% of yearly rainfall in Huang-Huai-Hai Plain, but wheat consumes normally more than 80% (from reviving, heading to ripping) of total water needed (Chen, 1996). Coincided with the dry and hot wind prevailing in the Plain at this time, the potential evaporation from March to June could be high as 300-400mm, which is about 3-4 times that of the precipitation of the same period. Total days, when the Yellow river runs out of water, has increased in recent years and caused many eco environmental problems in the low reach.

The issue of global climate change has become a common topic in the world and been closely related to water resources. One of conclusions of the project undertaken by Ye Duzheng[2] is that the temperature in North China in the year of 2030, compared with the current situation, is expected to raise at about 1.0-1.5°C in the winter and 0.5-0.8 °C in the summer, and the precipitation will remain more or less the same in the winter but increase 1-2% in the summer. The discharge in main rivers of North China, such as Haihe river and Luanhe river will decrease 3-6% due to the mixed effect of temperature and rainfall, and the runoff to Miyun Reservoir decline $2.4\ x10^8$ m^3.

Therefore, the water shortage problem rises as the consequence of not only natural factors but also social and economic aspects, and the reasons could possibly be summarized as follows:

- uneven distribution of rainfall in time and space
- the expansion of population and swift growth of economy
- the pollution of water resources
- low level of water re-use rate and poor water resource management

and possibly

- the consequence of global green-house effect and climate change

2. The impacts of water shortage on environment

As a result of natural, social and economic factors, the water shortage has feedback to all above factors and it could be an important element that constrains the sustainable development of economy and eco-environmental system. Because of this complex feedback, it is not easy to assess the impacts of water shortage on environment. Nonetheless, the impacts could basically be divided into two categories: direct and indirect, even though the boundary may not be clearly defined.

2.1 Direct impacts

[2] Li Bin, Chinese Science News, Dec. 2, 1996

Serving as one considerable component of entire eco-environmental system, water resources play a very important role in keeping the whole system sustainable. The water shortage, such as the diminishing of water body, does decline the environmental quality and disable the creature, which previously lives on it, to survive any longer. Taking Tarim river as an example, the extensive reclamation of farmland in upper stream and the water diversion to the irrigated area radically reduce the water to the low stream, resulting in the disappearance of Lop Nur. The low reach after Tikanlik was out of water after 1970, and thus its length was shorten about 200km. The environmental impacts of water shortage in this case can be judged as follows: (1) The extended dying of forest along the river bank, and the reduced capability against strong wind. (2) The degradation of range land. (3) The increasing potential in disaster of the gust of wind and sand, and the enlargement in desert. (4) The abandonment of farmland, and even having difficulty for local people in access to drinking water(Chen, 1993).

If the water shortage takes place in the coastal area of East China, where the economy has grown quickly in recent years and more and more water supply is needed, ground water will have risked of depletion and one serious environmental problem will arise: sea water intrusion. The survey in Laizhou city of Shandong Province has indicated that the area with ground water level lower than sea level has increases from 14.3 km^2 in 1979 to 262.05 km^2 in 1989(Fig.1), with average spread speed of about 25 km^2/year and the lowest ground water level of -16.74 m. Among the area of 262.05 km^2 in 1989, there are about 212.44 km^2, in which the content of CL^- of ground water is more than 300 mg/l and not suitable for irrigation (Yin, 1992). Most of these lands have to be relinquished without irrigation.

In order to cope with water shortage problem, many cities, especially in North China, have resort to groundwater, which unfortunately needs much more time than surface water in the process of circulation and can not be easily recovered if the aquifer suffers long excessive exploitation. If the aquifer could not be recharged and were left depleted, the problem of land subsidence would inevitably come up, such as the case in Tianjin city. The survey in Kaifeng city has showed that the area of depression(with groundwater depth more than 10 m) and the depth of groundwater in the center of it has reached 31.4 km^2 and 18.9 m in 1989, while only 2.2 km^2 and 12.1 m respectively in 1976[3]. The area and grade of land subsidence has closely related to the area and depth of groundwater depression.

The less water in the channel, the less power in transporting sediment, and the more sediment yield in the river bed. The relation of flow velocity(v) and the weight of transported sediment(W) could be expressed by Eley's law: $W=Av^6$, which means that a little change in the velocity will bring about large amount of variation in transported sediment. In the low reach of Yellow river, it is estimated that 40 m^3 of water is needed to transport 1 ton of sediment during flooding season, while 100 m^3 of water needed to transport the same amount of sediment during non-flooding season(Ye, 1994). Continuous addition of yield to Yellow river bed has caused many troubles, the most serious one could be the possible disastrous breaking up of the bank due to high altitude of the river bed in case of big flooding.

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[3] Shu longcang, Utilization of Water Resources and Environmental effects in Kaifeng City

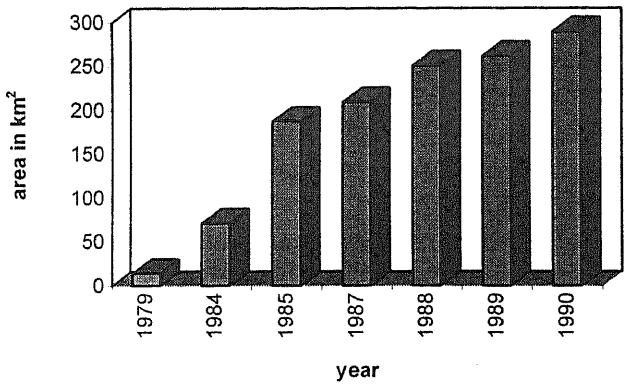

Figure 1 The development of area with groundwater level lower than sea level in Laizhou city(revised after Yin, 1992)

The water shortage has great effects on the mass and energy balance of water circulation. Generally, there are five components in the process of circulation, i.e., atmospheric water(P), surface water(R), plant water(V), soil water(S), groundwater(G), and there are possible ten combinations and interfaces between each two waters(Liu, 1993). SPAC(soil-plant-atmospheric continuum) initiated by J.R. Philip is actually the concept in dealing with the combination of P, V and S. The water shortage has impacts on all these components and the related hydrological process, in which: Precipitation = Runoff + Evapotranspiration.

The reduction of precipitation normally means the reduction in runoff and actual evapotranspiration, though potential evapotranspiration may increase, which will in turn effect precipitation and cause less and less rainfall. Even though this may not explain the formation of desert, it does indicate the hydrological process taking place there. Therefore, water shortage itself may cause the reduction of water resources, no matter how this seems to be puzzling, and probably this could be the most interesting impacts of shortage on environment. Water shortage is normally the result of many factors as mentioned in the former section, and its impacts on the mass and energy balance of water circulation and other environmental elements are very complex. The frame work of Fig.2 is the simplification of these complicated relations.

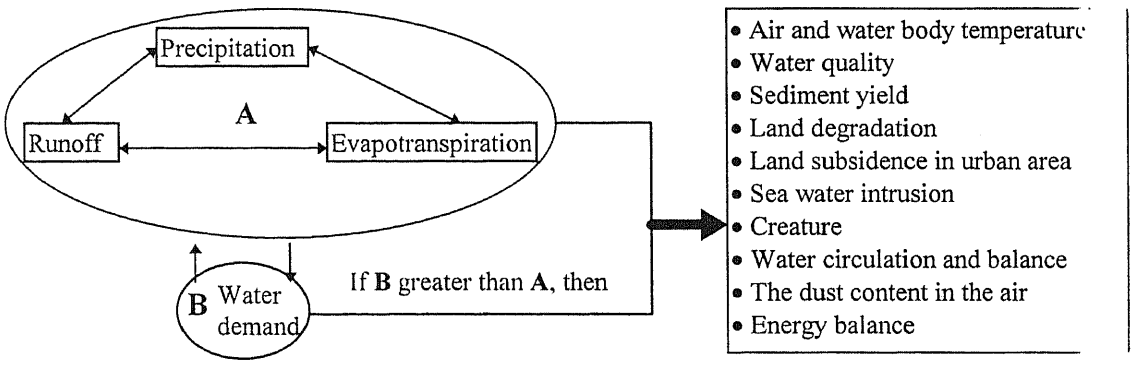

Figure 2 The context of water shortage and its environmental impacts

2.2 Indirect impacts

Many measures have been taken by human beings to cope with water shortage problem, such as building the reservoir and dam, transferring water from one area to another. The number of reservoir built in China up to 1989 is 82848, which accommodated total volume of 4617.31×10^8 m^3 .*[4] The east route of water transfer project is supposed to divert 1000 m^3/sec from south to north. All these efforts have definitely influenced the eco-environmental system. This has once been and will continue to be a disputable issue such as the case for the Three Gorges Project.

Another measure that people are taking and will have effects on environment is the enhancement of water management, which has been practiced in many cities of China. Water reuse rate is quite high in some cities, such as Tsingdao and Dalian. The present of water shortage may remind water users of its precious value and modify their ways in using water. Environmental quality will surely benefit from all of these practices

Most of waste water from factories has been discharged into the river without or with simple physical treatment due to insufficient fund and/or other reasons. Then, the less water used may mean the less polluted water to the river, and this also may do good to environment.

One measure called rainwater catchment system, i.e. to collect rainwater from impermeable pavement such as house roof and street, has played quite important role in the arid and semi-arid area of China, where annual average rainfall is about 400 mm. One program named "121" has been carried out in Gansu Province, in which every family develops 1 mu (one-fifteenth hec.) of impermeable area and collects rainwater water in two underground cells to irrigate 1 mu of crop field and supply domestic water use. One may argue that this measure will have great effects on runoff of the catchment and the other environmental aspects, and may not be suitable for extensive use. Actually, considering the size of impermeable area to the whole catchment, this measure may have only minor effects on the concerned aspects.

Because there are so many measures to reduce water shortage and its impacts as to sea water desalination, rainwater catchement system and even the proposal of drawing iceberg to coastal cities that it is hard to define fully the indirect impacts of water shortage on environment. Every measure may have its own impacts.

3. Policies to water shortage and its environmental impacts

The water shortage may break the mass and energy balance of the entire eco-environmental system, and a new balance needs to be reconstructed. The policies made help to ensure this reconstruction do less harm to the environment and human beings and people make the maximum profit from sustainable development of society, economy , natural resources and environment.

Therefore, the policies must concentrate on the sustainable development of limited water resources and the protection of vulnerable environment. Basically, there are two approaches in dealing with water shortage and its environmental impacts: to have new sources for water supply and to improve water management, and the latter should have the priority to the former one. The policies relevant to the impacts of water shortage on environment, either direct or indirect, are proposed as following:

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*[4] Yearly book of water conservation of China, 1990

- To educate human habitants on the earth to be aware of the importance of sustainable development of water resources and related environmental issues
- To encourage the use of technology to save water in both industry and agriculture.
- To take strict measures, such as increasing the price, to control the waste of water
- To set up laws to ensure the rational distribution of water resources
- To build rainwater catchment system in the arid and/or semi-arid region
- To constrain the expansion of population and industry in the area of poor water resources
- To make use of insurance policy to reduce the harm due to water shortage

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