Transboundary Aquifers in Great Mekong River Basin

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ABSTRACT

The Great Mekong River basins are located in the south-east part of Asia. There are four Transboundary aquifers among the countries, including China, Myanmar, Laos, Thailand, Cambodia and Vietnam. The groundwater resources in the basin are distributing in the plains, basins, plateaus and mountains. Development and utilization of underground water has a long history. At drought, groundwater is mainly used for irrigation and drinking residents' inland areas. In major cities, such as: Phnom Penh and some cities in Vietnam, the exploitation of groundwater is for urban water supply. Countries in the region should strengthen cooperation and exchange and research those transboundary aquifers, for coordination and joint management of groundwater resources in order to provide the scientific basis to achieve sustainable use of water resource. The DPSIR framework indicators are for the four trans-international boundary Aquifers in great Mekong River basin. Those aquifers could be scaled in to four grades on intrinsic value, Sensitive and Harmonious.

Key words: Great Mekong River, Transboundary aquifers, Environmental issues, Indicators

1. INTRODUCTION

The Great Mekong River is located in the northern part of Asia. It is an international river and through countries including China, Myanmar, Laos, Thailand, Cambodia, and Vietnam. The upstream is also named as Lancang River in China. The basin area of Great Mekong River is about 810 000 square km, the total distance from sources to the mouth is about 4880 km. Water resources in the Lancang River-Mekong River basin are abundance, but the surface water distribution is uneven in the time and space. The groundwater resources in the basin can are distributing in the plains, basins, plateaus and mountains. The development and utilization of shared water resources of international groundwater resources better meet the basin's water resources needs. The maintenance of international basin ecosystem balance is not only a regional theme of international cooperation, but also international organizations, research institutions and many non-governmental organizations. Water experts call for effectively improve the water-saving awareness, protect groundwater resources and the common shared aquifer resources, and establish water-saving society. Countries in the region should strengthen cooperation on transboundary aquifers, for coordination and joint management of groundwater resources in order to provide the scientific basis to achieve sustainable use.

2. TRANSBOUDARY AQUIFERS

Groundwater resource is an important fresh water resources and the transboundary aquifer is an important component of the groundwater system among the countries. There are four Transboundary aquifers in great Mekong River basin.

1.1 The aquifer in downstream of Lancang River

It is an aquifer shared by China and Myanmar, located at the juncture of Yunnan and Myanmar, and belongs to clastic rock fissure water. The area of the aquifer is 39509km^2, and the part in China is 31168km^2, accounting for 78% of the area of aquifer. The annual rainfall is 1000 ~ 1500mm.The supply conditions are good and natural supply module is between 10× 10^{4}m^3/km^2.a and 30 ×

$10^4m^3/km^2.a$. The chemical types of the groundwater are mainly for HCO_3-Ca.Mg and the TDS is 0.15 ~ 0.4g /l. The main lithology of the strata in the area is acidic intrusive granite rocks of Triassic, shale folder clay limestone of Jurassic, calcareous shale and sandstone folder mudstone, conglomerate mudstone folder siltstone and fine sandstone of Cretaceous. The intrusive rocks mainly distribute in the vicinity of Lincang and Jinghong and many fissures have developed. The large fault is the South Lancang fault zone and Wuliang Mountain fault zone. The north of the South Lancang fault is the Lancang River Valley on the west of Lanping, and it is south by Yongping, the north of Yunxian, through Jinghong extends into the territory of Myanmar from southwest and is a deep fault. The north of the Wuliang Mountain fault zone is Lanping; it is south by the east and west through Jinghong, the west of Zhenyuan to the southwest of Simao. Due to the impact of the fault zone, the tectonic fissures are rich; the contact position of acidic intrusive rocks and the surrounding rock is better rich in groundwater and is the large concentration water supply sources. The metamorphic rocks distribute from the east of the Lancang River to Zhenyuan - Simao area. The calcareous shale and argillaceous limestone of Jurassic is band spread. Most of the rock is with dense structure, less development cracks, poor tensional, strong capabilities resisting weathering, less developed weathering fissures. So the infiltration capacity is relatively low, and the storage groundwater is little.

1.2 The aquifer in midstream of Mekong River

The aquifer is a transboundary aquifer through Thailand, Myanmar and Viet Nam, and it belongs to fissure pore water in the plain and mountain basins. The area of aquifer is $106816km^2$, which in Myanmar is $77955.75km^2$,accounting for 73% of the total area, the part in Thailand accounts for 21% and the part in Vietnam accounts for only 6% of the total area. The annual rainfall in the region is between 900mm and 1600mm, Because the structure of the aquifer is complex and the supply conditions in different regions are relatively different, the difference between the amount of groundwater are also relatively large. The natural supply module is between $5 \times 10^4m^3/km^2.a$ and $40 \times 10^4m^3/km^2.a$. The aquifer is mainly affected by leaching and mixing and groundwater belongs to the bicarbonate and sulphuric acid type. The strata's of the aquifer expose continental classic sedimentary rocks of Jurassic, sandy conglomerate of middle and upper Cretaceous and the alluvial layer of Holocene. The continental clastic sedimentary rocks of Jurassic are scattered in the surrounding areas of Udon in Thailand, while a large number distribute in the surrounding of Phupan Mountains. The main lithologies are purple mudstone, calcareous mudstone folder sandstone. Fractures develop few, the permeability is poor water and it forms a relative aquifuge. The red or brown gravel and sandstone of Cretaceous are widely distributed in the aquifer, with the thickness of 60m ~ 300m and the average thickness of 125m or so. The fissure water is mostly in the form of layered, and the water abundance of the coarse particles rocks are generally better, the flow path is not long with characteristics of in suit recharge and in suit discharge. The groundwater quality is local fresh water underlying brackish water. The alluvial material of Holocene concentrated on both sides of the Mekong River is main alluvium, and the lithologies are sandy gravel layer, silt loam layer, salty sand and gravel bedded. The rocks are composed of the slate, siltstone, sandstone, and the rounding is good. The thickness of sediments changes relatively large and it is between 100m and 500m.The surface water and rainfall are relatively rich and the recharge rate is abundant. The natural supply module in this area is up to $40 \times 10^4m^3/km^2.a$, the water abundance of groundwater is good and the water content is rich.

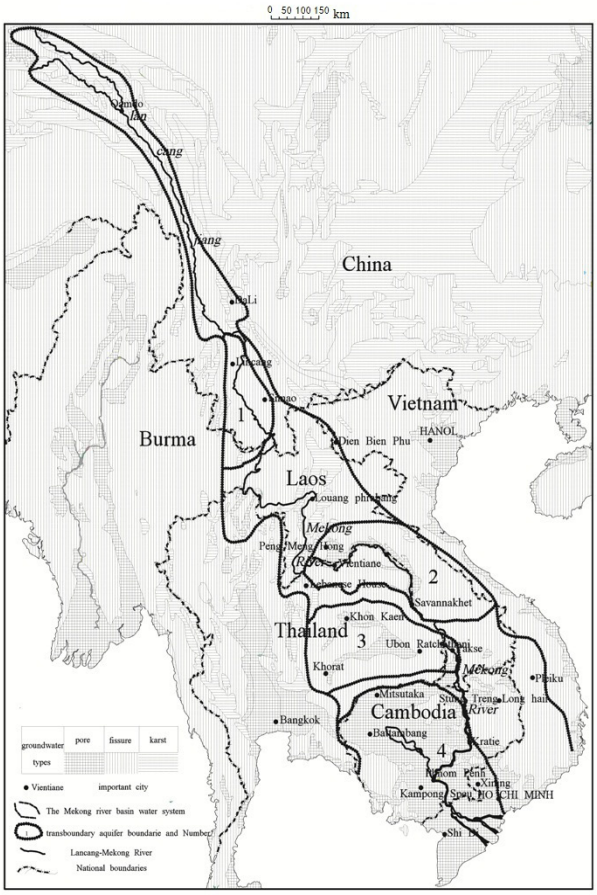
1.3 The aquifer in Kele plateau

The aquifer, shared by Thailand and Laos, is pore and fissure aquifer. The whole area is $95511km^2$. The area of Thailand is 90837.50 km^2, accounting for the most part, and Laos accounting for a little part in the northeast. The mean annual precipitation in this region is about 1000mm. The natural recharge modulus in most of the region reaches as high as $50\times10^4m^3/km^2.a$, and the local modulus is $50\times10^4m^3/km^2.a$ along the bank of Meng River and Xi River. The groundwater is salt water and brackish water. The sulphate and chloride type are the main chemical type. The strata are consisted mainly of Cretacic limestone, rhyolite, silexite and Holocene loose sediment. The loose sediment of river and lake phrase distributes along the banks of XI River (Tributary River of Mekong

River) and Meng River, with gravel and clay as the main lithology. The main recharge sources are atmospheric precipitation and river, the secondary is the lateral recharge from monotonic bedrock water. The natural recharge modulus is 30-50×$10^4$$m^3$/$km^2$.a for the wide recharge sources and good infiltration conditions. The strata in other areas are Cretacic stratum, consisting of red, purple and gray sandstone, siltstone, and shale, sand limestone, calcareous Siltstone. The aquifer is bedrock fracture water with undeveloped fissures. The natural recharge modulus is 5~10×$10^4$$m^3$/$km^2$.a. The east of the aquifer is Chang Shan mountain, with the elevation 2000~3000m. The lithology is mixed rock, gneiss and slate. Quaternary basic basalt spreads around Ba se in Laos, with developed weathering fissures. The natural recharge modulus is 20×$10^4$$m^3$/$km^2$.a.

Table 1 and Fig. 1 Transboundary aquifers in Great Mekong River basin

No	Aquifer	countries shared
1	The aquifer in downstream of The Lancang River	China, Burma
2	The aquifer in the mid of Mekong river	Thailand, Laos
3	The aquifer in Kele plateau	Thailand, Laos
4	The aquifer in Mekong river delta	Cambodia, Vietnam



1.4 Aquifer in Mekong river delta

The aquifer is shared by Cambodia and Vietnam. It is a typical flood alluvial basin, of which the east is Changshan Mountain in Vietnam, the west is Oula Mountain, and the north is Biandan Mountain. The whole area of the aquifer is 223423km^2, with Cambodia 141338 km^2, accounting for 63.3% of all. The length of Mekong river in Cambodia is about 1000km. Tonle Sap Lake water system affluxes Mekong river' downstream. As the largest lake in Cambodia and also IndoChina Peninsula, Tonle Sap Lake is a natural regulating reservoir of Mekong River. The annual precipitation in this region is between 1200mm and 2400mm, with Mekong river delta the biggest. The aquifer consists of Quaternary sediment, with 100-1000m in thickness. Biandan Mountain accented intensely and the delta plain sunk relatively in tectonic movement, thus very thick loose sediments were accumulated in mountain front, forming splendid water-bearing media. The natural recharge modulus is 30~50×$10^4$$m^3$/$km^2$.a. The groundwater environment transits from brackish water to salt water. The chemical type transits from bicarbonate, sulphate to chloride, for the process transits from leaching, mix to condensing and salting from north to south. The main recharge sources are precipitation,

surface water, and bedrock fissure water around. Meanwhile, there are lots of rivers in Mekong river delta, such as Tonle Sap Lake, Deep River, Saigon River, Hell River and some tributaries of Mekong River. Boulders and gravels expose from the top to the middle of alluvial fan, good for vertical intake from atmospheric precipitation. The natural recharge modulus is $30\times10^4 m^3/km^2.a$~$50\times10^4 m^3/km^2.a$. The lower delta has a good water storage capacity, as well as been a positive paretic zone. The most important fresh water aquifer is confined aquifer. Thin Holocene sediments formed not very thick phreatic aquifer generally. Extensive mid Pleistocene aquifer from coarse to fine sand spread in the north and south of the delta, with mineralization <1g/l commonly. The bottom Pleistocene aquifer which contains boulder, gravel and sand, is confined aquifer, with good groundwater quality, supplying 60% fresh water for the lower delta.

3. CHARACTERISTIC AND MAJOR ENVIRONMENTAL ISSUES

Upper Lancang River over the alpine region of Qinghai-Tibet Plateau is a sub-humid area, where there are critic weathering layer and thick layer, Strong infiltration, and snow are more melt water infiltrated into the ground and then flow to the rivers. Between Qamdo and Gongguo Bridge is the cross-sectional area mountain alpine valleys, river runoff is the type of rain - groundwater recharge mixed. Since then the following, before moving on to the low-lying Mekong, essentially the main supply belongs to rainwater supplying. Lowland of Mekong is a hilly mountain area of tropical moist, groundwater recharge to river prominent regulatory function, to Phnom Penh. Rivers accept the gradual increase of groundwater recharge. Tonle Sap Lake is a huge reservoir of natural regulation, when the downstream flow is more than $1500m^3/s$, it began to store flood water from the Delta, the flood inhaled up to 46 billion m^3. The groundwater resources in the basin can be divided to: in the plains and basins, in plateaus and mountains, in mountains and hills, and in freezing and thawing areas.

Development and utilization of groundwater has a long history. At inland areas drought, groundwater is mainly used for irrigation and drinking residents. In major cities, such as: Phnom Penh and some cities in Vietnam, the exploitation of groundwater is for urban water supply. According to the statistics of 41 major cities in South part of the basin, 20% of them rely on groundwater 39 % mainly surface water and groundwater as a supplement 41% only surface water In Vietnam, groundwater is the indispensable for urban water supply. At most areas, shallow groundwater is for drinking water. But in the main city, it had to increase the depth of the groundwater. In some cities because extraction groundwater is much larger than the natural recharge rate, the decline of groundwater levels begin to appear. The impact on the environmental aroused by groundwater development manifested in several issues. The negative impact of excessive exploitation of underground water cause the regional ground water level continued to drop; Land subsidence. If shallow groundwater levels can be control reasonable, groundwater generally can return to the critical depth of salt, making large areas of saline-alkali soil treatment. Exploitation groundwater along the riverside, it can increase recharge of groundwater. Source of groundwater pollution are included: point sources, surface sources and the proliferation sources. Point sources is refers to municipal solid waste landfill, accident of oil leakage and septic tank leakage. Surface sources refer to pollution of groundwater because of surface seepage. Irrigation water containing pesticides and fertilizers, unorganized rural towel waste water and other wastewater percolate through the soil. For excessive use chemical fertilizers and pesticides for farmland, so a large number of nitrogen and phosphorus nutrients and toxic chemicals, together with the leaching of water infiltrate into groundwater, which caused underground water pollution. We should give full consideration to the characteristics of the distribution of water, the rational use of surface water and groundwater resources.

4. CLASSIFY THE TBAS IN MEKONG RIVER BASIN WITH DPSIR INDICATORS

There are an attempt with DPSIR framework for Driving forces, Pressures, State Impact and Responses for classifications the transboundary aquifers in Mekong River basin. UNESCO-led expert group has proffered a precept on indicators for possible application of transboundary aquifers. The proposed methodology is relying on the assumption that the performance indicators will be used to

interventions among the TBAs. The potential benefits to be achieved in the case of TBAs depend on three sets of variables: Transboundary aquifers intrinsic value and functions, socio-economic and legal indicators. The Global Benefit Indexes (GBI) is probe into sub-indexes. TBAs indicators are measure of the potential of generate global environmental benefits; address more urgent and vulnerable situation.We used the identification and formulation for the four transboubdary aquifers A1, A2, A3 and A4 in Mekong River.

The weighting factors ω_i (0-1) assigned to the sub-indices have considerable influence on the outcome of the calculation and prioritization of TBAs.

4.1 Intrinsic value and functions indicators

Sub-Index	Indicator	A1	A2	A3	A4
1-1 Intrinsic Value and functions of groundwater	Mean annual rate of current groundwater recharge	3	3	2	3
	Aquifer storage capacity	1	2	2	3
	Groundwater natural quality	2	3	1	1
	Aquifer vulnerability	2	2	2	1
Scoring	$I_{IV} = (x_1 + x_2 + x_3 + x_4)/4$	2	2.5	1.75	2
1-2 Human environmental dependency groundwater	Human dependency on groundwater for drinking	3	2	1	3
	Dependency on groundwater for agriculture	2	2	1	2
	Ecosystem dependency on groundwater	2	2	2	2
Scoring	$I_{HE} = (x_1 + x_2 + x_3)/3$	2.33	2	1.33	2.33
1-3 Groundwater vulnerability to stress	Groundwater vulnerability to diffuse pollution	1	3	2	1
	Groundwater vulnerability to depletion	2	3	1	3
	Aquifer vulnerability to climate change	2	3	2	3
Scoring	$I_{VS} = (x_1 + x_2 + x_3)/3$	1.67	3	1.67	2.33
Global Benefit Indexes	$GBI = \sum_{i=1}^{3} \omega_i I_i \qquad (\sum_{i=1}^{3} \omega_i = 1)$	2.23	2.82	1.71	2.28

4.2 socio-economic and governance indicators

Sub-Index	Indicator	A1	A2	A3	A4
2-1 Socio-economic drivers, TB reform consistent with macro- socio - economic drivers	Sustainable socio-economic development for growth (GDP)	1	1	1	3
	Structural change: Sectored adjustment	2	1	1	2
	Sustainable national institutions	3	1	2	2
	National and regional security	2	2	2	3
	intensification for rural development food security	3	3	3	3
Scoring	$I_{SD} = (x_1 + x_2 + x_3 + x_4 + x_5)/5$	2.2	1.6	1.8	2.6
2-2 Economic instruments	Changing use costs Direct/indirect pricing	1	1	1	2
	Economic incentives	2	1	1	1
Scoring	$I_{EI} = (x_1 + x_2)/\ 2$	1.5	1	1	1.5
2-3 Economic governance Transboundary allocation	International resource/ trade/markets, quotas etc.	1	2	2	2
	Alternative economic governance structures	2	2	1	3
	Scope of associations successively expanded	3	1	2	2
	Successive spin-off for additional associations	3	2	3	3
Scoring	$I_{EG} = (x_1 + x_2 + x_3 + x_4)/4$	2.25	1.75	2	2.25
Global Benefit Indexes	$GBI = \sum_{i=1}^{3} \omega_i I_i \qquad (\sum_{i=1}^{3} \omega_i = 1)$	2.19	1.65	1.9	2.41

4.3 Legal and institutional indicators

Sub-Index	Indicator	A1	A2	A3	A4
3-1 Cooperation	Existence of agreement on TBA among riparian countries	2	2	1	2
	Agreement on other water bodies	3	2	2	3
	Ratification of international or regional framework convention on international / transboundary waters	2	1	2	2
	Participation to a process or project on TBAs	1	1	1	1
Scoring	$I_c = (x_1 + x_2 + x_3 + x_4)/4$	2	1.5	1.5	2
3-2 Legal and institutional framework	Water law	2	2	2	1
	Provisions on Groundwater or regulation on Groundwater	3	2	2	1
	Absence of legal framework on water resources	3	1	1	1
	Institutions: Dealing with water	2	2	2	2
Scoring	$I_L = (x_1 + x_2 + x_3 + x_4)/4$	2.5	1.75	1.75	1.25
Global Benefit Indexes	$GBI = \sum_{i=1}^{2} \omega_i I_i \quad (\sum_{i=1}^{2} \omega_i = 1)$	2.21	1.68	1.65	1.85

According to the indicators, the trans-international boundary Aquifers could be scaled in to four grades. The GBI is (1-1.5), (1.5-2), (2-2.5) and (2.5-3) respectively. With the Intrinsic value and functions indicators, the aquifers could be scaled into Low, Medium-low, Medium-high and High. With the socio-economic and governance indicators, the aquifers could be scaled into: Most Sensitive, More Sensitive, sensitive and insensitive. With the Legal and institutional indicators, the aquifers could be scaled into: Inconsistent, Lesser Harmonious, Harmonious and more Harmonious.

5. CONCLUSIONS

Countries in Lancang - Mekong River Basin should strengthen cooperation on the four transboundary aquifers, for coordination and joint management of groundwater resources in order to provide the scientific basis to achieve sustainable use of water resource. According to the classification with DPSIR framework, the aquifer in downstream of Lancang River is a Medium-high, Sensitive and Harmonious aquifer. The aquifer in midstream of Mekong River is a High, More Sensitive and Lesser Harmonious aquifer. The aquifer in Kele plateau is a Medium-low, More Sensitive and Lesser Harmonious aquifer. The aquifer in Mekong river delta is a Medium-high, Sensitive and Lesser Harmonious aquifer.

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