International Journal of the Malay World and Civilisation (Iman) 5(Special Issue 1), 2017: 97 - 105
(http://dx.doi.org/10.17576/IMAN-2017-05SI1-13)

Urbanization Trends and Groundwater Issues in Asian Cities

Trend Pembandaran dan Isu Air bawah tanah di Bandaraya Asia

Neethu Vijaya, Shaharudin Idrus, Mazlin Mokhtar, Nimisha Krishnankutty

ABSTRACT

Above half of the global population resides in urban areas and the increasing population is highly dependent on groundwater for its drinking water and agricultural requirements. Asia and Africa are urbanizing at a higher rate than other developed regions. Asia contributes to 53 percent of global urban population and is expected to reach 55 percent by 2025. This article seeks to explore the urbanization trends in Asia and its impacts on groundwater resources through evaluating five countries- China, India, Indonesia, Japan and Malaysia. China and India are two major contributors of world's urban population; Indonesia, Japan and Malaysia are other three rapidly urbanizing countries in Asia. The analyses are drawn based on a critical review of previous studies conducted on the topic in Asia. The study has found that most populous mega-urban regions in the world and in Asia are located in these five countries. The urban growth rate of China is double or little less than India, Indonesia and Malaysia; Japan is expected to exhibit a declination in its urban population while continue to maintain a high urbanization level during 2014-2050. Urbanization in Asia is not environmentally sustainable and it puts huge pressure on groundwater resources, degrading its quality and quantity, raising concern for resultant land subsidence. India poses a higher pressure on its groundwater resources, followed by China, Indonesia, Japan and Malaysia. Innovative technological and governance solutions with given priority on infrastructural development and environmental conservation is required to tackle urbanization dilemma existing in Asia.

Keywords: Asia; urbanization; groundwater; Sustainable Development; infrastructure

ABSTRAK

Lebih daripada separuh penduduk dunia tinggal di kawasan bandar dan penduduk yang semakin bertambah adalah sangat bergantung kepada air bawah tanah untuk air minuman dan keperluan pertanian. Asia dan Afrika mengalami proses pembandaran pada kadar yang lebih tinggi berbanding kawasan-kawasan maju yang lain. Asia menyumbang kepada 53 peratus daripada penduduk bandar global dan dijangka mencapai 55 peratus pada tahun 2025. Penulisan ini bertujuan untuk meneroka tren urbanisasi di Asia dan kesan ke atas sumber air bawah tanah. Lima negara Asia menjadi tumpuan kajian adalah China, India, Indonesia, Jepun dan Malaysia. China dan India adalah dua penyumbang utama penduduk bandar dunia; Indonesia, Jepun dan Malaysia tiga negara pesat pembandaran di Asia. Analisis dibuat berdasarkan kajian kritikal, kajian sebelum ini dijalankan pada topik di Asia. Kajian ini telah mendapati bahawa kawasan yang paling ramai penduduk mega-bandar di dunia dan di Asia terletak di kelima-lima negara. Kadar pertumbuhan bandar di China adalah dua kali ganda atau sedikit kurang daripada India, Indonesia dan Malaysia; Jepun dijangka mempamerkan kemerosotan penduduk bandar di samping terus mengekalkan tahap pembandaran yang tinggi semasa 2014-2050. Perbandaran di Asia tidak mencemarkan alam sekitar tetapi meletakkan tekanan yang besar kepada sumber air bawah tanah, kualiti dan kuantiti air bawah tanah semakin berkurang, meningkatkan kebimbangan berlakunya pemendapan tanah. India menimbulkan tekanan yang lebih tinggi kepada sumber air bawah tanah, diikuti oleh China, Indonesia, Jepun dan Malaysia. Penyelesaian teknologi dan tadbir urus inovatif diberi keutamaan kepada pembangunan infrastruktur dan pemuliharaan alam sekitar diperlukan untuk menangani dilema pembandaran yang sedia ada di Asia.

Kata kunci: Asia; pembandaran; air bawah tanah; Pembangunan Lestari; infrastruktur

INTRODUCTION

Majority of global population resides in urban areas. The first phenomenon of global urban population exceeding over global rural population occurred in 2007, and since then the scenario remained same. In 1950, 70 percent of global population was settled in rural areas and 30 percent was in urban areas (United Nations, Department of Economic and Social Affairs, Population Division 2014). Later in 2014, the urban population has grown to 54 percent. Additionally, it is estimated that the growing urban population will constitute two-third of the global population by 2050, reducing rural population to be one-third (United Nations, Department of Economic and Social Affairs, Population Division 2014). Then, it will witness the reverse process of urban-rural population existed in 1950's. The rapidly growing population in the world depends on groundwater for about 50 percent of its drinking water requirements and 43 percent of its agricultural needs (Treidel et al. 2011).

Groundwater is a vital component of hydrological cycle and it supports agricultural, industrial and domestic water requirements worldwide. About 1.5-2.8 billion people depend on groundwater for drinking water and about half of the megacities in the world rely on groundwater for agricultural and developmental needs (Giordano 2009). It plays a crucial role in the sustenance of surface water bodies such as streams, ponds, lakes and wetlands. However, human developmental activities and climate change consequences have seriously threatened groundwater resources. There are several studies that focus on impacts of anthropogenic activities and climate change on more visible surface water systems compared to groundwater resources beneath the earth surface. Understanding the functioning of subsurface hydrological system, its interaction with external factors such as development, climate change and its sustainable management for global water security is of a greater challenge. Groundwater is often described as "an invisible, silent, or hidden resource" (Giordano 2009). Groundwater has several advantages over surface water; it is less vulnerable to seasonal fluctuations, widely distributed underneath the earth surface, less polluted and can be cheaply produced (Heng 2004). Therefore, groundwater is overly exploited by human beings for household, industrial and developmental needs and it has threatened both the quantity and quality of groundwater resources worldwide.

Asia is rapidly urbanizing than other regions in the world and water shortage is a huge challenge in the region. Therefore this study seeks to explore the urbanization trends in five major Asian countries- China, India, Indonesia, Japan and Malaysia, and its consequences on the quality and quantity of groundwater resources in the region. China and India has been chosen as they are the two major contributors of Asian and global urban population as well as major consumers of groundwater resources. Indonesia, Japan and Malaysia are also rapidly urbanizing in the last decades and thus expected to represent other Asian countries. The analysis is mainly drawn based on review of previous studies and reports in the region in the recent years. Urbanization trend and groundwater resources in the world in brief, Asia and in the selected five countries in depth are discussed in the paper. Recommendations for sustainable urbanization and management of groundwater resources are suggested.

URBANIZATION AND GROUNDWATER RESOURCES IN ASIA

Urbanization is occurring worldwide, but the rate of urbanization varies from regions to regions. Asia and Africa is urbanizing at a higher rate than Europe, Latin America and the Caribbean, North America, and Oceania. India and China in Asia and Nigeria in Africa is predicted to contribute to 37% of global urban population between 2014 and 2050 (United Nations, Department of Economic and Social Affairs, Population Division 2014).

URBANIZATION TREND IN ASIA

Contrary to the lower level of urbanization in Asia, it hosted 53 percent of the total global urban population of 3.9 billion in 2014 (United Nations, Department of Economic and Social Affairs, Population Division, 2014). The Europe in the second position only has 14 percent of world's urban population and the Latin America and the Caribbean in the third position has only 13 percent. While the developed regions have very nearly or more than three fourths of their population residing in urban areas, Asia and Africa remain mostly rural with urban proportion of 48 percent and 40 percent respectively (See Table 1). However, Asia and Africa is expected to grow at a faster rate in terms of urbanization than other regions in the world. It is estimated that Asia will attain 64 percent and Africa at 56 percent of urban population by 2050, which will still remain less compared to global urban population of 66 percent and other regions (United Nations, Department of Economic and Social Affairs, Population Division 2014). At present the rate of urbanization in Asia and Africa is 1.5 percent and 1.1 percent respectively while other regions with higher urban population are only growing at a rate less than 0.4 percent yearly (United Nations, Department of Economic and Social Affairs, Population Division 2014). Asia will be the centre of global urbanization process and about 2.6 billion in Asia will inhabit in urban areas by 2025, covering a 55% of global urban population (Sankhe et al. 2011).

TABLE 1. Urban population in the world and in major regions in the world

Major region, country, or area	Population in thousands						Proportion urban (per cent)			Average Annual rate of change (per cent)
	Urban			Rural						
	1990	2014	2050	1990	2014	2050	1990	2014	2050	2010-2015
World	2 285 031	3 880 128	6 338 611	3 035 786	3 363 656	3 212 333	43	54	66	0.9
Africa	196 923	455 345	1 338 566	433 064	682 885	1 054 609	31	40	56	1.1
Asia	1 036 247	2 064 211	3 313 424	2 176 877	2 278 044	1 850 638	32	48	64	1.5
Europe	505 991	545 382	581 113	217 257	197 431	127 954	70	73	82	0.3
Latin America & the Caribbean	313 876	495 857	673 631	131 327	127 565	107 935	71	80	86	0.3
Northern America	212 935	291 860	390 070	69 351	66 376	56 130	75	81	87	0.2
Oceania	19 059	27 473	41 807	7 911	11 356	15 067	71	71	74	0

Source: United Nations, Department of Economic and Social Affairs, Population Division 2014

GROUNDWATER RESOURCES IN ASIA

Groundwater is ubiquitous, but the quantity and quality of available groundwater differs from place to place. Studies so far have identified 273 aquifers in the world and most of them are transboundary. As per the World - wide Hydrogeological Mapping and Assessment Programme (WHYMAP), about 35% of the continental area excluding Antarctic has homogeneous aquifers which are potential for groundwater exploitation. About 18% is composed of aquifers in a geologically complex setting; they exist heterogeneously in folded or faulted regions and are highly productive (See Fig. 1). However, about half of the continent (47%) is endowed with local and shallow aquifers, accessed to limited amount of population (Richts et al. 2006). Similarly, Asia has about 32% (14.54 million km^2) major groundwater basins, 17.3% (7.84 million km^2) aquifers in complex hydrogeological settings, and 50.7% (22.98 million km^2) local and shallow aquifers (BGR/UNESCO 2008b).

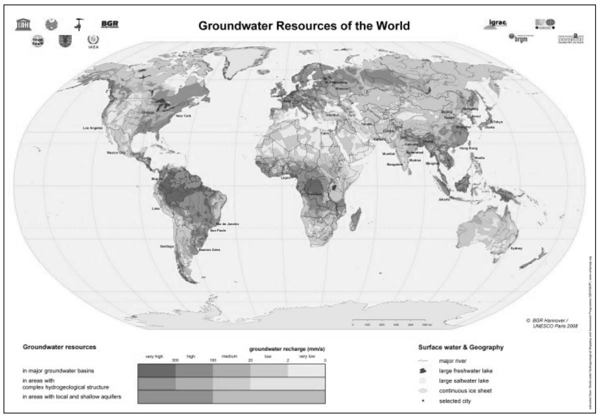

FIGURE 1: Groundwater Resources of the World

Source: BGR Hannover/UNESCO, 2008a

URBANIZATION IN CHINA, INDIA, INDONESIA, JAPAN, AND MALAYSIA

Among the 10 recognized most populous cities in 2013, seven are situated in Asia-Pacific region including Tokyo, Delhi, Shanghai, Mumbai, Beijing, Dhaka, and Kolkata (United Nations-ESCAP 2013). Evidently, most of them are located in China, India, and Japan. In 2014, China, Hong Kong SAR (Special Administrative Region), and China, Macao SAR had 54 percent, 100 percent, 100 percent urban population respectively. India had about 32 percent. By 2050, it is estimated that more than three fourth of the Chinese population and half of the Indian population will be urban (See Fig. 2). Japan is expected to hit its urban population to 98 percent by 2050, while Malaysia will reach 84 percent and Indonesia at a higher pace will attain 71 percent (United Nations, Department of Economic and Social Affairs, Population Division 2014). Among the countries, the average annual rate of change (%) in urban population of China during 2010-2015 periods is nearly double compared to other countries. The rate of urban growth in China is 2.4 percent, where as in India, Japan, Indonesia and Malaysia is 1.1 percent, 0.6 percent, 1.5 percent and 1 percent respectively.

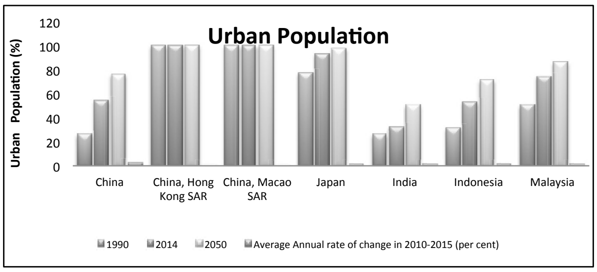

FIGURE 2. Urban Population & Rate of Growth in China, Japan, India, Indonesia and Malaysia

Most of the world's largest urban agglomerations are located in Asia. Tokyo in Japan is the largest city in the world with a population of 38 million inhabitants, followed by Delhi with 25 million, Shanghai with 23 million and Mexico City, Mumbai and Sao Paulo, each with about 21 million inhabitants (United Nations, Department of Economic and Social Affairs, Population Division 2014). It is estimated that Tokyo's population will reduce by 2020, but will remain the world's largest agglomeration with a population of 37 million in 2030. Delhi will continue to grow and will maintain the second largest agglomeration in world with a population of 36 million, an additional 11 million over 16 years.

China and India are the main contributors of urban population in Asia. Studies show that China and India will constitute more than one-third of global urban population growth in 2014-2050 (United Nations, Department of Economic and Social Affairs, Population Division 2014). India and China are expected to add a population of 404 million and 292 million respectively during this period. About half of India's urban population is currently concentrated in six states- Maharashtra, Gujarat, Tamilnadu, Karnataka, Punjab and West Bengal (Kundu 2011). Apart, Delhi, Mumbai, and Kolkata, four other Indian cities- Ahmadabad, Bangalore, Chennai and Hyderabad- with current urban population between 5 to 10 million people are expected to transform into megacities. Thus, India will host about 7 megacities by 2030. Similarly, at present China has six megacities and ten other cities with population between 5-10 million. By 2030, one more megacity and six more large cities will be added. Though China is undergoing urbanization at a faster rate than India in a systematic approach, India had an advantage over China in its population trend. While China will have larger urban population, India will have more young urban population (Sankhe 2011). In India, it is expected that the proportion of economically active group (15-59 years old) will be 68% by 2030 from 63% in 2001, and is expected to continue the trend in the coming few decades. Contrary, China is projected to experience decline in its economically active age group from 70% at present to 67% by 2030 (Kundu 2011). India will have this advantage over many other developing countries in terms of its positive age structure.

Besides China and India, Indonesia is a rapidly urbanizing country in Asia. Indonesia (134 million), China and India (30 percent of world urban population), Japan, United States of America, Brazil, and the Russian Federation now contributes to more than half of the world's urban population. During 2014-2050, Indonesia is expected to add more than 50 million to urban population while Japan is expected to witness largest decline of 12 million in urban population compared to other countries (United Nations, Department of Economic and Social Affairs, Population Division 2014). Urbanization in Indonesia, especially during the economic boom in 1980s and 1990s, experienced rapid land conversion from residential areas, slums, agricultural lands to urban land use (residential areas, industrial estates, golf courses, and tourist resorts). This can be clearly observed in its larger cities such as Jabotabek (Jakarta Metropolitan area), Surabaya, and Bandung (Firman 2004). Further, Indonesia being a rapidly urbanizing country with more than 50% of urban population encounters a negative co-relation with growth of economic output due to lack of investment on infrastructure by government. The country has poor quality in infrastructure in terms of water, electricity, roads, ports, rail roads and air transport; consequently, World Bank (2011) has identified Indonesia as a unfavourable place to invest in business (Lewis 2014).

Malaysia is also in pace with its Asian counterparts in urbanization growth rates. Rapid urbanization began in Malaysia since 1970, and transformed the country from an agricultural to an industrial based economy (Hasan and Nair 2014). Urbanization in Malaysia can be described in a three phase process- nascent (1514-1947), pseudo (1948-1970) and emergence of mega urban regions (1971-Beyond) (Idrus et al. 2010). During the emergence of mega urban regions, most of the towns introduced during colonial period in Malaysia has undergone huge expansion, resulting in a rapid increase in number of towns from 72 in 1980 to 228 in 2010 (Hasan and Nair 2014). Malaysia had about 58 metropolitan towns in 2010, including Kuala Lumpur, Klang, Johor Bahru, and Petaling Jaya. The urban population of Malaysia in 1970 was 26.8% (Hasan and Nair 2014) and which has increased to 74% in 2014 (United Nations, Department of Economic and Social Affairs, Population Division 2014). This drastic change in urbanization has been occurred mainly due to the spatial distribution occurred from migration, influenced by various government strategies and policies such as new Economic policy in 1970 and successive five year plans (Hasan and Nair 2014).

China, India, Indonesia, Japan and Malaysia are urbanizing faster competing each other and among other Asian counterparts. As a result, Asia currently hosts 16 megacities in the world, and the number is expected to hike in the coming decades.

GROUNDWATER RESOURCES IN CHINA, INDIA, INDONESIA, JAPAN, AND MALAYSIA

The total actual renewable water resources (TARWR) in a country depends on its precipitation, surface water and groundwater produced internally, surface water and groundwater entering and leaving the country, and overlap between surface water and groundwater. The data on total population, precipitation, total renewable water resources and total actual renewable resources per inhabitant for the five countries are given in Table 2. China has the highest total actual renewable water resources, followed by Indonesia, India, Malaysia and Japan, where as the TARWR per inhabitant is highest for Malaysia, and then Indonesia, Japan, China and India.

TABLE 2. Total Renewable Water Resources in China, India, Indonesia, Japan and Malaysia

Country	Total Population		Precipitation	Renewable Water Resources					Total Actual Renewable Resources (TARWR) per inhabitant	
	2001	2011	Long-Term Annual Average	SW produced internally	GW produced internally	Overlap between SW & GW	(IRWR)	(TARWR)	2001	2011
	1000 inhabitants		(mm/year)			(km3/year)			(m3/year)	
China	1307 271	1378 506	645	2712	828.8	727.9	2813	2840	2172	2060
India	1071 374	1241 492	1083	1404	432	390	1446	1911	1784	1539
Indonesia	2162 03	2423 26	2702	1973	457.4	411.7	2019	2019	9338	8332
Japan	1258 94	1264 97	1668	420	27	17	430	430	3416	3399
Malaysia	2396 5	2885 9	2875	566	64	50	580	580	2420 2	2009 8

Source: FAO-AQUASTAT Database, 2015

Millennium Development Goal (MDG) water indicator shows the proportion of freshwater withdrawal in comparison to total actual renewable water resources and it indicates the pressure on renewable water resources. From the Figure 3, it is evident that pressure on renewable water resources is high in India with 33.9%. India is followed by China with 19.5%, Japan by 20.9%, Indonesia by 5.612 % and Malaysia by 1.9%.

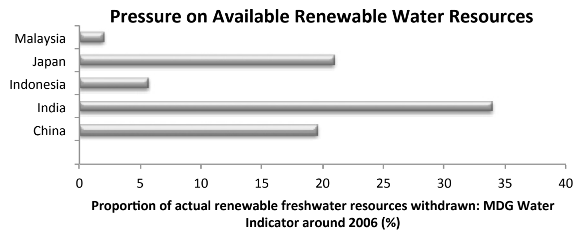

FIGURE 3. Pressure on Available Renewable Water Resources (Millennium Water Indicator) in China, India, Indonesia, Japan and Malaysia

Groundwater is an important water resource globally. As a raw material, groundwater is hugely extracted in the world at a rate of 982 km3/yr (National Groundwater Association 2015). Major sectors of global groundwater consumption include agriculture (60%), domestic and industrial use, which consume the left proportion equally. India remains first position in the world in terms of largest estimated annual groundwater extraction (2010), followed by China in second position, Indonesia in ninth and Japan in thirteenth position. See Table 3 for detailed data on groundwater extraction in the five countries. About 2,058 million people in the world depended on boreholes and dug wells for drinking water in 2010, of which 406 million were urbanites, while the dependent urban population was 249 million in 1990 (National Groundwater Association 2015). This evidently shows the dependency of increasing urban population on groundwater for their water requirements.

TABLE 3. Annual Groundwater Extraction

Country	Groundwater Extraction			
	Estimated groundwater extraction 2010 (km3/yr)	Break down by sector		
		Groundwater extraction for irrigation (%)	**Groundwater extraction for domestic use (%)**	**Groundwater extraction for industry (%)**
India	251	89	9	2
China	111.95	54	20	26
Indonesia	14.93	2	93	5
Japan	10.94	23	29	48
Malaysia	0.165	5	60	35

Source: National Groundwater Association 2015; Food and Agriculture Organization of the United Nations 2015b; Suratman, S. 2015

*Annual groundwater extraction statistics (2005): India, China, Indonesia and Japan
*Annual groundwater extraction statistics (1996): Malaysia

URBANIZATION CONSEQUENCES ON GROUNDWATER RESOURCES: CHINA, INDIA, INDONESIA, JAPAN AND MALAYSIA

Urbanization enables centres of knowledge, cultural diversity, and business initiatives for economic efficiency; however, it also cause emergence of several environmental and developmental dilemma. One of the major challenges Asian megacities encounters is densification of the city core due to lack of proper infrastructural facilities at the urban fringes (United Nations – ESCAP 2013). It will lead to road congestion, inequalities and poverty among urbanites especially among migrant labourers, emergence of criminal activities, inadequate sanitation and solid waste management facilities, poor air quality and water scarcity (United Nations – ESCAP 2013; United Nations, Department of Economic and Social Affairs, Population Division 2014).

Urbanization, pollution of surface water resources and water scarcity has led to overexploitation of groundwater resources. Groundwater extraction is much higher than recharging in majority of the regions. India and China, two big consumers of food and groundwater resources, highly depend on groundwater for their agricultural activities. Lack of groundwater can risk about one quarter of India's food production, while one-half of North China's Plain's wheat production (United Nations, Department of Economic and Social Affairs, Population Division 2014). Over exploitation of groundwater can cause decline in groundwater table. For example, it has been reported that in many parts of alluvial aquifers of Indo-Gangetic plains in South Asia and hard rock aquifers in southern Indian peninsula that the water tables are falling at a rate of 1m or more per year in the last 20 years or more. Similarly, groundwater level in Ajmer city in India has dropped to 3-16 m due to reduction in groundwater recharge (Jat et al. 2009) and China also witnessed decline in water level by 1.5 m per year in the last 10 years (Giordano 2009). This decline could lead to saltwater intrusion. For example, Jakarta, in Indonesia experiences drinking water scarcity as well water is inappropriate for drinking due to saltwater intrusion (Jones 2002). Huge extraction of groundwater resources for households, agricultural and industrial needs are the major reasons behind salt water intrusion.

Over-extraction of groundwater resources and compaction due to urbanization can lead to land subsidence. It could cause adverse impacts to urban infrastructure as well ground-surface water interactions. Land subsidence could disrupt natural base flow in rivers, streams, wetlands, associated ecosystems and biota. It will also affect soil moisture, agriculture, cost of drilling wells, its management and water yield. Urbanization also affects groundwater quality. Urbanization mainly contaminates both surface and groundwater resources biologically (from human and animal waste) and chemically (industrial and agricultural runoff). For instance, major rivers in Langat River Basin- one of the most urbanized basin in Selangor state, Malaysia, are highly polluted with organic matters, suspended solids, and various heavy metals (Yusuf 2001) and groundwater is detected with arsenic and iron contamination (JICA and MGDM 2002). The pollution sources include development activities, agricultural farms, mines, landfills, waste water treatment plants and petroleum storage tanks. Rise in temperature in urban areas (heat island effect) can lead to increase in subsurface temperature, thereby altering the groundwater systems geochemically and microbiologically affecting its quality (Taniguchi et al. 2007). For instance, it is estimated that the air temperature in Tokyo increased by 2.96^{o}C 100 y^{-1} and the penetration depth of increasing surface temperature due to urbanization in Tokyo is about 140 m, where deviation from geothermal gradient has been observed (Taniguchi et al. 2007).

Therefore, urbanization is directly linked with groundwater at multiple levels. While unplanned urbanization could cause decline in groundwater table and degradation of groundwater quality, over extraction of groundwater could lead to land subsidence, threatening the long-term existence of mega-urban regions, especially ones near shorelines. The unplanned urbanization and its impacts on the quality and quantity of groundwater resources points to the unsustainable development occurring in Asian region. Awareness creation, innovative technologies, required governance strategies and policies need to be undertaken to guide the development in the right track as well as to conserve groundwater resources for water and food security.

SUSTAINABLE MANAGEMENT OF GROUNDWATER RESOURCES

Safe yield, meaning the maximum quantity of water which can be extracted from an underground reservoir, yet still maintain the supply impaired (Gleick 2001), was the core of the traditional groundwater management till the concept of sustainable development emerged in World Commission on Environment and Development (1987). It defined sustainable development as, 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Du Pisani 2006). Later, sustainability of water resources began with the realization that by 2025, one third of world's total population will not have access to fresh drinking water (Gleick 2001).The concept of sustainability evolved from the comprehension of inevitable interdependence of environment and society. Groundwater sustainability is defined as: "the development and use of groundwater resources in a manner that can be maintained for an indefinite time without causing unacceptable, environmental, economic or social consequences (Gleick 2001). Therefore, sustainability yield promotes integrated water management approaches such as conjunctive use of surface water and groundwater resources, artificial recharge and use of recycled or reclaimed water. In the century of environment where urbanization and climate change are the major antagonists, sustainable development of groundwater resources is challenging but vital.

CONCLUSIONS AND RECOMMENDATIONS

Asia is one of the major drivers of global urban population growth and the major megacities of the world are situated in China, India, Japan, and some in Indonesia and Malaysia. These growing megacities are highly depending on groundwater resources to meet their domestic, agricultural and industrial needs. Urbanization has adverse impacts on both the quantity and quality of groundwater resources. Increased demand has led to over abstraction of groundwater resources and has reduced its quantity; drying of wells, salt water intrusion and land subsidence are its after-effects. Quality problem mainly includes pollution from agricultural, developmental activities or industries. Through reviewing the urbanization trend in China, India, Indonesia, Japan and Malaysia, it has been found that the urbanization in Asia is not environmentally sustainable.

To mitigate the urban consequences on groundwater resources and socio-economic disparities in Asia, there is a need of improved urban governance involving stakeholder participation, which will address the specific needs of the city and its population. Governance should also give priority and investment for infrastructural development in both urban areas and small cities. It will enhance availability of raw materials, improved interlink between production centres and markets, easy transportation between rural and urban areas, lessen pressure at the urban centre, and empower small cities and towns to compete at global level. Governing bodies should also ensure through developmental initiatives and policies that the benefits of urbanization are equally distributed among people in different social strata. Apart, an environmentally sustainable developmental approach should be followed to adapt to environmental degradation caused by urbanization and other contemporary challenges such as climate change. Initiatives and technological innovations should be undertaken to adapt to increasing atmospheric temperature, degrading air quality, increasing waste problems, and contamination of both surface and groundwater resources, all rooted in urbanization process. Sustainable management of groundwater resources in a region needs to consider existing water problems in relation to social, economic, and legal aspects that are unique to the particular scenario. Hydrologists and engineers need to unite to develop required innovations to determine locally specific sustainable yield, integrated management of surface and groundwater resources and efficient recharging of these resources for indefinite use.

REFERENCES

BGR/UNESCO. 2008a. Groundwater Resources of the World. Bundesanstalt fur Geowissenschaften und Rohstoffe. http://www.whymap.org/whymap/EN/Home/gw_world_g.html. Last Accessed 1 September 2015.

BGR/UNESCO. 2008b. Statistics. Bundesanstalt fur Geowissenschaften und Rohstoffe. http://www.whymap.org/whymap/EN/Statistics/statistics_node_en.html. Last Accessed 5 September 2015.

Du Pisani, J. A. 2006. Sustainable Development–Historical Roots of the Concept. *Environmental Sciences* 3(2): 83-96.

FAO- AQUASTAT Database. 2015a. Water Resource Information by Country/Territory and MDG Water Indicator. Food and Agriculture Organization of the United Nations (FAO). http://www.fao.org/nr/water/aquastat/water_res/index.stm. Last Accessed 25 October 2015.

FAO- AQUASTAT Database. 2015b. Water Withdrawal by Source. Food and Agriculture Organization of the United Nations (FAO). Accessed 14 October 2015.

Firman, T. 2004. Major Issues in Indonesia's Urban Land Development. *Land Use Policy* 21(4): 347-335.

Giordano, M. 2009. Global groundwater? Issues and solutions. *Annual Review of Environment and Resources* 34: 153-178.

Gleick, P. H. 2001. Safeguarding Our Water: Making Every Drop Count. *Scientific American* 284: 40-45.

Hasan, A. R. & Nair, P. L. 2014. Urbanisation and Growth of Metropolitan Centres in Malaysia. *Malaysian Journal of Economics Studies* 51(1): 87-101.

Heng, C. L. 2004. Groundwater utilisation and management in Malaysia. In Proceedings of the 41 st CCOP (Coordinating Committee for Geoscience Programmes in East and Southeast Asia) Annual Session (15-18 November 2004) Tsukuba, Japan, 83.

Idrus, S., Hadi, A. S., Shah, A. H. H., & Rainis, R. 2010. Neighbourhood Expansion and Urban Livability in Seremban Municipality Area, Malaysia. *Malaysian Journal of Environmental Management* 11(1): 37-47.

Jat, M. K., Khare, D. and Garg, P. K. 2009. Urbanization and its Impact on Groundwater: a Remote Sensing and GIS-based Assessment Approach. *The Environmentalist* 29(1):17-32.

JICA and MGDM. 2002. The study on the Sustainable Groundwater Resources and Environmental Management for the Langat Basin in Malaysia. Kuala Lumpur.

Jones, G. W. 2002. Southeast Asian Urbanization and the Growth of Mega-Urban Regions. *Journal of Population Research* 19(2): 119-136.

Kundu, Amitabh. 2011. Trends and Processes of Urbanization in India. Human Settlements Group, International Institute for Environment and Development (IIED) and Population and Development Branch, United Nations Population Fund (UNFPA).

Lewis, B. D. 2014. Urbanization and Economic Growth in Indonesia: Good News, Bad News and (Possible) Local Government Mitigation. *Regional Studies* 48(1): 192-207.

National Groundwater Association.2015. Facts About Global Groundwater Usage. National Groundwater Association.

Richts, A., Struckmeier, W., & Zaepke, M. 2006. *WHYMAP-Looking at Groundwater from a Global Perspective*.

Federal Institute for Geosciences and Natural Resources (BGR), Hannover/Germany.

Sankhe, S., Vittal, I., & Mohan, A. 2011. Urban Giants: India and China and their Urbanization Paths. *Environment and Urbanization Asia* 2(1): 1-12.

Suratman, S. 2015. *IWRM: Managing the Groundwater Component in Malaysia*. Minerals and Geoscience Department Malaysia.

Taniguchi, M., Uemura, T., & Jago-on, K. 2007. Combined effects of urbanization and global warming on subsurface temperature in four Asian cities. *Vadose Zone Journal* 6(3): 591-596.

Treidel, H., Martin-Bordes, J. L., & Gurdak, J. J. (Eds.). 2011. *Climate Change Effects on Groundwater Resources: A Global Synthesis of Findings and Recommendations*. CRC Press.

United Nations, Department of Economic and Social Affairs, Population Division. 2014. World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352).

United Nations – ESCAP. 2013. Factsheet: Urbanization trends in Asia and the Pacific. Economic and Social Commission for Asia and the Pacific.

Yusuf, M. A. 2001. River Water Quality and Ecosystem Health in Langat Basin, Selangor, Malaysia. Ph.D. Dissertation, Institute for Environment and Development, Universiti Kebangsaan Malaysia.

Neethu Vijayan
Institute for Environment and Development (LESTARI)
Universiti Kebangsaan Malaysia
43600 Bangi, Selangor
Malaysia

Shaharudin Idrus
Institute for Environment and Development (LESTARI)
Universiti Kebangsaan Malaysia
43600 Bangi, Selangor
Malaysia
E-mail: dinn6358@ukm.edu.my

Mazlin Bin Mokhtar
Institute for Environment and Development (LESTARI)
Universiti Kebangsaan Malaysia
43600 Bangi, Selangor
Malaysia
E-mail: mazlin@ukm.edu.my

Nimisha Krishnankutty
Faculty of Science and Technology
Universiti Kebangsaan Malaysia
43600 Bangi, Selangor
Malaysia

Received: 21 October 2015
Accepted: 16 April 2016