BY EMAIL ONLY

Mr. WONG Kam Sing, JP
Secretary for Environment
Interdepartmental Working Group on Climate Change
Email: sen@enb.gov.hk

23 March, 2016

Dear Mr. Wong,

Adapting to Climate Change in Hong Kong (II)
Evaporation of Reservoir Water Due to Global Warming

In response to the climate agreement of 2015 Paris Climate Conference (COP21), Hong Kong should take a more proactive role to combat and adapt to the adverse impacts of global warming in order to protect people's life and health, the ecosystem and minimize the associated economic loss.

Currently, on average Hong Kong's 2500 hectare reservoir system loses 30.68 million cubic meters of water annually through evaporation, which are only equivalent to 3.2% of annual potable water needs of 950 million cubic metres, or 5.2% of the total capacity 586 million cubic metres of local reservoirs. Evaporation seems to play no role in Hong Kong's potable water supply.

However, the extreme climate events may occur in the future under climate change. If severe drought prevails for a period in South China, freshwater supply from Dongjiang may be affected. Then, evaporation of local reservoir water will become significant to Hong Kong's water supply.

Few local studies were conducted on this aspect. Therefore, Green Power preliminarily explores the impacts of climate change on evaporation of local reservoir. The rough calculation predicted the future hidden economic loss due to increase in evaporation of reservoir water under global warming. Our society will lose 1.54 to 9.25 million cubic metres of potable water which worth HK$ 11.84 to 71.03 million per year to Hong Kong.

We believe that this amount may only represent a very tiny portion of external cost of climate change, as climate change impacts not only potable water resources but also a much wider scope including power supply, food supply, public's health, infrastructure, and also economy (consumerism, insurance, etc.).

Therefore, the government must lead the Hong Kong's society to recognize the potential impacts of climate change, and formulate surveillance and adaptation measures to minimize any impacts on all sectors of the society.

Yours sincerely,

CHENG Luk-ki
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GREEN POWER

Encl. A brief paper on "Adapting to Climate Change in Hong Kong (II) - Evaporation of Reservoir Water Due to Global Warming"

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Adapting to Climate Change in Hong Kong (II)
Evaporation of Reservoir Water Due to Global Warming

By Green Power
22 March 2016

Foreword

1. This brief paper continues the works of previous one released in November, 2015 themed "Adapting to Climate Change in Hong Kong" to explore the impacts of climate change in certain neglected or less concerned aspects.

Introduction

2. Evaporation is a significant part of the global water cycle. It is a physical process that water escapes into the atmosphere invisibly in the form of water vapour from the water surfaces of water bodies such as oceans, rivers, lakes and reservoirs under ambient temperature. The rate of evaporation depends on the conditions of water surfaces and meteorological factors including air temperature, humidity, wind speed, cloud cover and etc.

3. Global warming is intensifying as a consequence of increase in greenhouse gas concentration in the Earth's atmosphere. Therefore, a rise in temperature will raise evaporation rate generally. However, it should be noted that at the same time it may increase cloud cover and rainfall which will offset the effect of evaporation.

4. The evaporation of reservoir water in Hong Kong and South China will accelerate due to the elevated temperature. However, few local studies were conducted on this aspect. Green Power preliminarily explores the impacts of climate change on evaporation rate of reservoirs of our water supplies system as example. We anticipate initiate more relevant in-depth researches in local context. The results are essential to Hong Kong to prepare for adaptation to climate change that may lead to more stringent potable water supply.

Projection of Local Air Temperature

5. Analysis of the annual mean temperature data recorded at the Hong Kong Observatory (HKO) Headquarters showed that there was an average rise of 0.12℃ per decade from 1885 to 2015. The rate of increase in average temperature became faster in the latter half of the 20th century, reaching 0.17℃ per decade during 1986-2015.[1]

6. The HKO utilizes data of a number of computer climate models in the IPCC Fifth Assessment

[1] Observed Climate Change in Hong Kong, Hong Kong Observatory: http://www.hko.gov.hk/climate_change/obs_hk_temp_e.htm

Report (AR5) and statistical method with urbanization effect on temperature incorporated to project the temperature changes in Hong Kong in the 21st century (Table 1).[2]

Table 1. Temperature projection for Hong Kong by the HKO compared to the 1986-2005 average of 23.3°C

	Mid-21st Century (2051-2060)	Late 21st Century (2091-2100)
High greenhouse gas concentration scenario	1.5-3°C	3-6°C
Medium-low greenhouse gas concentration scenario	1-2°C	1.5-3°C

7. As temperatures increase in projected climate change in Hong Kong, Hong Kong is more vulnerable to the loss of potable water due to higher evaporation rate of the reservoirs which stores potable water.

Past Evaporation Monitoring Results

8. Evaporation measurements are made daily at King's Park using Class A evaporation pans with evaporation surface 0.18 m above ground. In general, the amount of evaporation depends on the amount of solar radiation received, the relative humidity as well as the wind speed. [3]

9. Annual mean evaporation rate recorded at King's Park between 1981-2010 is 1227.3mm which is about half of the annual mean rainfall of 2398.5mm recorded at the HKO.[4]

10. According to the HKO, accompanying the decrease in solar radiation and wind speed, the annual total evaporation recorded at King's Park also decreased at a rate of 111 mm per decade, according to a regression fit for the period of 1961-2015.[3]

11. However, a rising trend has observed since 1990 with a rate of 60 mm per decade.

Evaporation Rate and High Temperature

12. The higher the temperature, the faster the evaporation is. When temperature rises, part of the heat absorbed by water will be taken to give off water vapour, i.e. evaporation. At the same time, warmer air above the water surface can hold more water vapour that promotes evaporation.

13. In order to project the evaporation rate in the territory due to change in air temperature, the relationship between evaporation rate and temperature should be established in the first place. However, air temperature is not the only or major factor contributing to change in evaporation

[2] Projections of Hong Kong Climate for the 21st century, Hong Kong Observatory: http://www.hko.gov.hk/climate_change/proj_hk_temp_e.htm

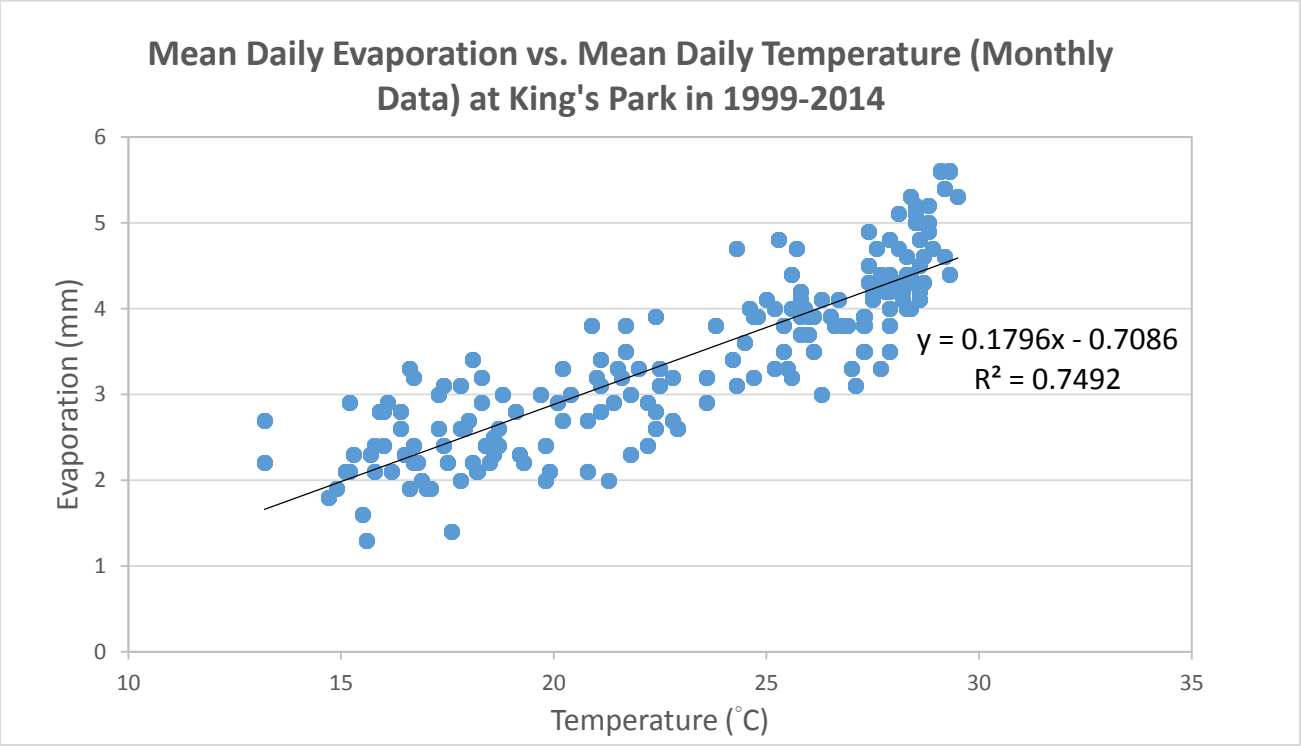
[3] Observed Climate Change in Hong Kong, Cloud amount, solar radiation and evaporation, Hong Kong Observatory: http://www.hko.gov.hk/climate_change/obs_hk_cloud_e.htm

[4] Monthly Meteorological Normals for Hong Kong, Hong Kong Observatory: http://www.hko.gov.hk/cis/normal/1981_2010/normals_e.htm#table2

rate. There is also no simple theoretical correlation of evaporation rate and air temperature. For estimation, linear regression of mean daily evaporation rate and mean daily air temperature are utilized to establish an approximate quantitative dependence of evaporation rate on air temperature.

14. The correlation between evaporation rate and air temperature is analyzed by reviewing the HKO's data from 1999-2014 collected in King's Park respectively. Mean daily evaporation rates obtained by measurement of Class A pan were plotted against corresponding daily mean temperatures which is shown in Figures 1.

Figure 1:



15. Although evaporation rate is affected by various meteorological factors other than air temperature, the graph shows that the measured evaporation rates are roughly directly proportional to air temperature in the observed range.

16. The linear regression indicates an increase of 0.18 mm daily evaporation rate (Class A pan) for rise in 1°C. So, the estimated increase in annual evaporation rate is 65.66 mm for rise in 1°C. In order to estimate the evaporation rate of reservoir, Class A pan evaporation rate is multiplied by a correction factor of 0.75.[5] Then, the dependence of annual evaporation rate of reservoirs on air temperature is estimated to be 49.17 mm for rise in 1°C.

[5] Simple Methods for Aquaculture, FAO Training Series: ftp://ftp.fao.org/fi/cdrom/fao_training/FAO_Training/General/x6705e/Index.htm

17. Before the end of 21st century, the HKO projected a rise in temperature ranged from 1.0 to 6.0°C compared to the 1986-2005 average of 23.5°C (Table 1) which is corresponding to an additional evaporation of 49.17 to 294.99 mm reservoir water.

Loss of Reservoir Water by Evaporation

18. Singapore's 3000 hectare reservoir system loses more than 60 million cubic meters of water annually through evaporation[6], which are equivalent to 20-22% of annual potable needs. This evaporation loss reduces supplies not only from rainwater, but also from all other sources stored in the reservoirs, including water brought in from neighbouring Malaysia.

19. In the US, the reservoir water loss is becoming even more important as broad uncertainties in precipitation projected by climate change which is an issue already affecting the growing population of the West.[7]

20. In fact, a report produced by the United Nations Environment Programme shows that globally more water evaporates from reservoirs than is consumed by humans.[8]

21. In contrary, the annual evaporation rates for the period of 1961-2015 observed by the HKO shows a declining trend.[3] However, Hong Kong should keep alert towards the possibility of reverse evaporation trend and change in rainfall under climate change.

22. The total surface area of Hong Kong's reservoirs is about 25 km^2.[9] An additional evaporation of 49.17 to 294.99 mm reservoir water is estimated before the end of 21st century which is corresponding to loss of 1.23 to 7.37 million cubic metres. This volume is equivalent to 10-55% of the capacity of Shing Mun Reservoir. The total capacity of Hong Kong's reservoirs is 586 million cubic metres.[10]

23. The production cost of drinking water from local reservoirs and Dongjiang is HK$4 and $8.60 per cubic metres respectively.[11] Hong Kong's freshwater consumption comprises about 25% local and 75% Dongjiang source (which is stored in local reservoirs). Therefore, the average

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[6] P. Suresh Babu1, Hans S. Eikaas, Anthony Price & David Verlee, *Reduction of Evaporative Losses from Tropical Reservoirs using an Environmentally Safe Organic Monolayer,* Catchment and Waterways Department, Public Utilities Board, Singapore: http://www.flexiblesolutions.com/products/watersavr/documents/ReductionofEvaporativeLossesfromTropical.pdf

[7] *Reservoir evaporation a big challenge for water managers in West*, News Center, University of Colorado Boulder, December 28, 2015 http://www.colorado.edu/news/releases/2015/12/28/reservoir-evaporation-big-challenge-water-managers-west#sthash.DQ4mzZ4T.dpuf

[8] VITAL GRAPHICS, UNEP/GRID-ARENDAL, UNEP: http://www.unep.org/dewa/vitalwater/article46.html

[9] Land Utilization in Hong Kong 2014, Planning Department: http://www.pland.gov.hk/pland_en/info_serv/statistic/landu.html

[10] Water Supplies Department: http://www.wsd.gov.hk/waterconservation/en/origin_of_water3.html

[11] Water resources in HK, Section 3.2, Research Brief Issue No.5, 2014-2015, Research Office, Legco Secretariat: http://www.legco.gov.hk/research-publications/english/1415rb05-water-resources-in-hong-kong-20150611-e.pdf

production cost of potable water from local reservoirs is HK$ 7.45.

24. A yearly extra loss of 1.23 to 7.37 million cubic metres by evaporation of local reservoir water implies a monetary loss of HK$ 9.16 to 54.94 million per year.

25. The total surface area of reservoirs of Dongjiang Water Supplies System to Hong Kong is 6.34 km^2. A yearly extra additional evaporation of 49.17 to 294.99 mm reservoir water is estimated before the end of 21st century which are corresponding to loss of 0.31 to 1.87 million cubic metres.

26. About one-tenth of Dongjiang water supplies Hong Kong and the cost of drinking water from Dongjiang water is about HK$8.6.[11] A yearly extra loss of 0.31 to 1.87 million cubic metres reservoir water implying a monetary loss of HK$ 2.68 to 16.08 million per year.

Realizing and Preparing for the Impacts of Climate Change

27. Compared to Singapore, currently on average Hong Kong's 2500 hectare reservoir system loses 30.68 million cubic meters of water annually through evaporation, which are only equivalent to 3.2% of annual potable water needs of 950 million cubic metres, or 5.2% of the total capacity 586 million cubic metres of local reservoirs. Evaporation seems to play no role in Hong Kong's potable water supply.

28. However, the extreme climate events may occur in the future under climate change. If severe drought prevails for a period in South China, supply from Dongjiang may be affected. Then, evaporation of local reservoir water will become significant to Hong Kong's water supply.

29. The rough calculation aforementioned predicted the future hidden economic loss due to increase in evaporation of reservoir water under global warming. Our society will lose 1.54 to 9.25 million cubic metres of potable water which worth HK$ 11.84 to 71.03 million per year to Hong Kong.

30. This amount may only represent a very tiny portion of external cost of climate change, as climate change impacts not only potable water resources but also a much wider scope including power supply, food supply, public's health, infrastructure, and also economy (consumerism, insurance, etc.).

31. The government must lead the Hong Kong's society to recognize the potential impacts of climate change, and formulate surveillance and adaptation measures to minimize any impacts on all sectors of the society.

THE END