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Supplementary Information for

Sustainable Application of a Novel Water Cycle Using Seawater for Toilet Flushing

Xiaoming Liu [a,b,c], Ji Dai [a,b,c], Di Wu [a,b,c], Feng Jiang [d], Guanghao Chen [a,b,c], Ho-Kwong Chui [a,c], Mark C. M. van Loosdrecht [e,*]

[a] *Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong, China*
[b] *Water Technology Center, The Hong Kong University of Science and Technology, Hong Kong, China*
[c] *Chinese National Engineering Research Center for Control and Treatment of Heavy Metal Pollution (Hong Kong Branch), The Hong Kong University of Science and Technology, Hong Kong, China*
[d] *School of Chemistry and Environment, South China Normal University, Guangzhou 510006, China*
[e] *Department of Biotechnology, Delft University of Technology, Delft 2629 HZ, the Netherlands*

Table S1
Water and geographical conditions for Hong Kong, Shenzhen, Beijing, and Qingdao.

	Hong Kong	Shenzhen	Beijing	Qingdao
Annual water withdrawal (10^8 $m^3·a^{-1}$)[a]	12.2 [1]	18.0 [2]	23.5 [3]	6.0 [4]
Toilet flushing amount ($m^3·(person·a)^{-1}$)[b]	34 [1]	34	34	34
South-to-North Water Diversion Project (SNWDP) amount (10^8 $m^3·a^{-1}$)	—	—	3.70 [5]	1.46 [5]
Transportation distance of freshwater by SNWDP (km)	—	—	1 432 [5]	1 467 [5]
Imported water amount except that from SNWDP (10^8 $m^3·a^{-1}$)[c]	7.09 [1]	14.40 [2]	2.52 [3]	2.08 [4]
Transportation distance of freshwater except that by SNWDP (km)	85 [1]	85 [2]	112 [3]	276 [4]
Urban population[d] (10^4 persons)	707 [6]	1 050 [7]	1 850 [8]	500 [9]
Living area[e] (km^2)	280 [10]	1 200	2 500	1 300
Effective population density (persons·km^{-2})	25 000	8 700	7 400	3 800
Population density in Wikipedia (persons·km^{-2})[f]	6 415	5 200	1 261	1 426

[a] Annual water withdrawal only accounts for the water for domestic and urban industry use. Water for agriculture, environmental supplement, and power plants is not considered, because this portion of water does not go through the domestic pipeline systems.
[b] The amount of water used for toilet flushing per person in Shenzhen, Beijing, and Qingdao is assumed to be the same as that used in Hong Kong [1].
[c] Hong Kong and Shenzhen import freshwater from Dongjiang River. Besides importing water from the SNWDP, Beijing and Qingdao also import freshwater from Miyun Reservoir and Yellow River, respectively.
[d] Only people living in urban areas are counted, because the population in rural areas is too sparse and a separate pipeline for toilet flushing is not efficient.
[e] Non-living areas such as forests and lakes are excluded, because no pipes go through these areas. Except for Hong Kong, living areas are calculated using Google Maps. In order to improve robustness, ±20% uncertainty is considered.
[f] The population density in Wikipedia is the average population, accounting for both living and non-living areas, which cannot be used for pipeline calculations.

Table S2
Water consumption and allocation for different urban water system scenarios in Hong Kong (10^8 $m^3·a^{-1}$).

Scenario	Imported from Dongjiang River	Local fresh-water	SWTF	RO desalinated water	Wastewater reclamation for toilet flushing	Total water requirement	Conventional activated sludge process	SANI process
FWA	9.49	2.71				12.20	9.76	
FRA		2.71		9.49		12.20	9.76	
DSA	7.09	2.71	2.40			12.20	9.76	
DSS	7.09	2.71	2.40			12.20		9.76
DNA	7.09	2.71			2.40	12.20	9.76	

SWTF: seawater for toilet flushing; RO: reverse osmosis; SANI: sulfate reduction, autotrophic denitrification, and nitrification integrated.

* Corresponding author.
E-mail address: M.C.M.vanloosdrecht@tudelft.nl

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Table S3
Water consumption and allocation for different urban water system scenarios in Shenzhen (10^8 $m^3 \cdot a^{-1}$).

Scenario	Imported from Dongjiang River	Local freshwater	SWTF	RO desalinated water	Wastewater reclamation for toilet flushing	Total water requirement	Conventional activated sludge process	SANI process
FWA	14.40	3.60				18.00	14.40	
FRA		3.60		14.40		18.00	14.40	
DSA	10.83	3.60	3.57			18.00	14.40	
DSS	10.83	3.60	3.57			18.00		14.40
DNA	10.83	3.60			3.57	18.00	14.40	

Table S4
Water consumption and allocation for different urban water system scenarios in Beijing (10^8 $m^3 \cdot a^{-1}$).

Scenario	Imported from the SNWDP	Imported from Miyun Reservoir	Local freshwater	SWTF	RO desalinated water	Wastewater reclamation for toilet flushing	Total water requirement	Conventional activated sludge process	SANI process
FWA	3.70	2.52	17.28				23.50	18.80	
FRA		2.52	14.69		6.29		23.50	18.80	
DSA		2.52	14.69	6.29			23.50	18.80	
DSS		2.52	14.69	6.29			23.50		18.80
DNA		2.52	14.69			6.29	23.50	18.80	

Table S5
Water consumption and allocation for different urban water system scenarios in Qingdao (10^8 $m^3 \cdot a^{-1}$).

Scenario	Imported from the SNWDP	Imported from Yellow River	Local freshwater	SWTF	RO desalinated water	Wastewater reclamation for toilet flushing	Total water requirement	Conventional activated sludge process	SANI process
FWA	1.46	2.08	2.46				6.00	4.80	
FRA		2.08	2.22		1.70		6.00	4.80	
DSA		2.08	2.22	1.70			6.00	4.80	
DSS		2.08	2.22	1.70			6.00		4.80
DNA		2.08	2.22			1.70	6.00	4.80	

Table S6
Inventory for the conventional water treatment plant, assuming a 50-year lifetime (unit is based on treatment flow).

	Input value	Source[a]
Steel rebar	0.4 $kg \cdot m^{-3}$	Collected in Hong Kong
Concrete	3.1×10^{-3} $kg \cdot m^{-3}$	Collected in Hong Kong
Timber	5.54 $kg \cdot m^{-3}$	Collected in Hong Kong
Energy	0.15 $kW \cdot h \cdot m^{-3}$	Collected in Hong Kong
Steel work	1.21×10^{-2} $kg \cdot m^{-3}$	Collected in Hong Kong
Liquid chlorine	1.7×10^{-3} $kg \cdot m^{-3}$	Collected in Hong Kong
Hydrate lime	9.6×10^{-3} $kg \cdot m^{-3}$	Collected in Hong Kong
Alum	1.56×10^{-2} $kg \cdot m^{-3}$	Collected in Hong Kong
Sodium silicofluoride	5.0×10^{-4} $kg \cdot m^{-3}$	Collected in Hong Kong

[a] Data collected from the Tai Po water treatment plant through personal communication with local engineering consultants.

Table S7
Inventory for water distribution and sewage collection in Hong Kong (unit is based on water flow transported).

	Input value	Source
Pipelines for freshwater and wastewater reclamation distribution, assuming a 50-year lifetime		
Polyethylene	1.3×10^{-3} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
PVC	2.5×10^{-3} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Cast iron	5.0×10^{-5} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Concrete	1.5×10^{-2} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Steel	2.0×10^{-2} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Diesel	3.0×10^{-3} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Oil for engine	4.5×10^{-5} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Gasoline	7.5×10^{-4} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Electricity[a]	3.0×10^{-1} kW·h·m^{-3}	Collected in Hong Kong[b]
Pipelines for seawater toilet flushing, assuming a 20-year lifetime		
Polyethylene	3.2×10^{-3} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
PVC	6.5×10^{-3} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Cast iron	1.3×10^{-4} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Concrete	4.0×10^{-2} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Steel	5.2×10^{-2} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Diesel	7.5×10^{-3} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Oil for engine	1.1×10^{-4} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Gasoline	1.9×10^{-3} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Electricity[a]	3.0×10^{-1} kW·h·m^{-3}	Collected in Hong Kong[b]
Freshwater sewage collection, assuming a 50-year lifetime		
Ceramic	1.0×10^{-4} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
PVC	2.0×10^{-6} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Cast iron	1.0×10^{-4} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Concrete	5.5×10^{-2} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Steel	4.5×10^{-4} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Diesel	2.0×10^{-3} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Oil for engine	3.3×10^{-5} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Gasoline	7.5×10^{-4} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Electricity[c]	0 kW·h·m^{-3}	Refs. [12–14]
Mixed sewage collection, assuming a 40-year lifetime		
Ceramic	1.2×10^{-4} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
PVC	2.4×10^{-6} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Cast iron	1.2×10^{-4} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Concrete	6.6×10^{-2} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Steel	5.4×10^{-4} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Diesel	2.0×10^{-3} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Oil for engine	3.3×10^{-5} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Gasoline	7.5×10^{-4} kg·m^{-3}	Estimated from Barjoveanu et al. [11]
Electricity[c]	0 kW·h·m^{-3}	Refs. [12–14]

PVC: polyvinyl chloride.

[a] Based on the Water Supplies Department (WSD) report [1], the energy consumption associated with seawater distribution is considered with a deduction of service head of around 30 m. We assume that freshwater and seawater consume the same amount of energy to reach the same destination during the distribution process. The freshwater energy consumption in the WSD report includes the total energy consumed for water treatment and distribution.

[b] Data collected from the WSD and the Drainage Services Department of the Government of the Hong Kong Special Administrative Region through personal communication with local engineering consultants.

[c] Sewage collection relies on gravity flow.

Table S8
Inventory for a wastewater treatment plant (unit is based on treatment flow).

	CASP, assuming a 50-year lifetime		CASP with mixed sewage, assuming a 40-year lifetime		SANI process, assuming a 40-year lifetime	
	Input value	Source	Input value	Source[a]	Input value	Source
Cement	8×10^{-3} kg·m^{-3}	Estimated	1.0×10^{-2} kg·m^{-3}	Collected in Hong Kong	1.0×10^{-2} kg·m^{-3}	Assumed to be same as CAS
Concrete	2.4×10^{-2} kg·m^{-3}	Estimated	2.9×10^{-2} kg·m^{-3}	Collected in Hong Kong	2.9×10^{-2} kg·m^{-3}	Assumed to be same as CAS
Steel	3.0×10^{-3} kg·m^{-3}	Estimated	3.7×10^{-3} kg·m^{-3}	Collected in Hong Kong	3.7×10^{-3} kg·m^{-3}	Assumed to be same as CAS
Iron	3.7×10^{-5} kg·m^{-3}	Estimated	4.2×10^{-5} kg·m^{-3}	Collected in Hong Kong	4.2×10^{-5} kg·m^{-3}	Assumed to be same as CAS
PVC	0.8×10^{-6} kg·m^{-3}	Estimated	1.0×10^{-6} kg·m^{-3}	Collected in Hong Kong	1.0×10^{-6} kg·m^{-3}	Assumed to be same as CAS
Electricity	0.41 kW·h·m^{-3}	Estimated	0.41 kW·h·m^{-3}	Collected in Hong Kong	0.27 kW·h·m^{-3}	Ref. [15]
Ferric chloride solution, 40%a	2.9×10^{-3} kg·m^{-3}	Estimated	2.9×10^{-3} kg·m^{-3}	Collected in Hong Kong	0	Ref. [16]
Calcium nitrate solution, 50%a	2.5×10^{-2} kg·m^{-3}	Estimated	2.5×10^{-2} kg·m^{-3}	Collected in Hong Kong	0	Ref. [16]
Polyelectrolyte	2.5×10^{-3} kg·m^{-3}	Estimated	2.5×10^{-3} kg·m^{-3}	Collected in Hong Kong	0	Ref. [16]
Carbon dioxide	3.1×10^{-3} kg·m^{-3}	Ref. [17]	3.1×10^{-3} kg·m^{-3}	Ref. [17]	3.1×10^{-3} kg·m^{-3}	Assumed to be same as CAS
Methane	3.8×10^{-3} kg·m^{-3}	Ref. [17]	3.8×10^{-3} kg·m^{-3}	Ref. [17]	3.8×10^{-3} kg·m^{-3}	Assumed to be same as CAS
Nitrous oxide	5.8×10^{-4} kg·m^{-3}	Ref. [17]	5.8×10^{-4} kg·m^{-3}	Ref. [17]	5.8×10^{-4} kg·m^{-3}	Assumed to be same as CAS
Ammonia	1.4×10^{-3} kg·m^{-3}	Ref. [17]	1.4×10^{-3} kg·m^{-3}	Ref. [17]	1.4×10^{-3} kg·m^{-3}	Assumed to be same as CAS
SO_x	7.7×10^{-4} kg·m^{-3}	Ref. [17]	7.7×10^{-4} kg·m^{-3}	Ref. [17]	7.7×10^{-4} kg·m^{-3}	Assumed to be same as CAS
BOD_5	5.0×10^{-3} kg·m^{-3}	Collected in Hong Kong	5.0×10^{-3} kg·m^{-3}	Collected in Hong Kong	5.0×10^{-3} kg·m^{-3}	Assumed to be same as CAS
TSS	1.0×10^{-2} kg·m^{-3}	Collected in Hong Kong	1.0×10^{-2} kg·m^{-3}	Collected in Hong Kong	1.0×10^{-2} kg·m^{-3}	Assumed to be same as CAS
TN	1.0×10^{-2} kg·m^{-3}	Collected in Hong Kong	1.0×10^{-2} kg·m^{-3}	Collected in Hong Kong	1.0×10^{-2} kg·m^{-3}	Assumed to be same as CAS
Sludge incineration						
CO_2	132 kg·(tDM)$^{-1}$	Ref. [15]	132 kg·(tDM)$^{-1}$	Ref. [15]	0	Ref. [15]
Particles emission	2.0 μg·(tDM)$^{-1}$	Ref. [18]	2.0 μg·(tDM)$^{-1}$	Ref. [18]	0	Ref. [15]

CASP: conventional activated sludge plant; BOD_5: 5 day biochemical oxygen demand; TSS: total suspended solid; TN: total nitrogen; tDM: 1 ton of dried mineral.
[a] Data collected from the Sha Tin Sewage Treatment Works through personal communication with local engineering consultants.

Table S9
Inventory for importing water from Miyun Reservoir in Beijing via 112 km of canal, assuming a 100-year lifetime (unit is based on water flow transported).

	Input value	Source
Cement	1.1×10^{-2} kg·m^{-3}	Estimated from Li et al. [5]
Gravel	3.0×10^{-2} kg·m^{-3}	Estimated from Li et al. [5]
Sand	1.3×10^{-2} kg·m^{-3}	Estimated from Li et al. [5]
Brick	5.3×10^{-6} kg·m^{-3}	Estimated from Li et al. [5]
Steel	2.4×10^{-3} kg·m^{-3}	Estimated from Li et al. [5]
Cast iron	9.0×10^{-6} kg·m^{-3}	Estimated from Li et al. [5]
Copper	5.2×10^{-6} kg·m^{-3}	Estimated from Li et al. [5]
Aluminum	4.2×10^{-6} kg·m^{-3}	Estimated from Li et al. [5]
Energy	8.1×10^{-2} kW·h·m^{-3}	Estimated from Li et al. [5]

Table S10
Inventory for seawater importation from the seaside to Beijing via 270 km of canal, assuming a 100-year of lifetime for the construction part and a 20-year lifetime for the pumping station (unit is based on water flow transported).

	Input value	Source
Cement	2.6×10^{-2} kg·m^{-3}	Estimated from Li et al. [5]
Gravel	8.4×10^{-2} kg·m^{-3}	Estimated from Li et al. [5]
Sand	3.7×10^{-2} kg·m^{-3}	Estimated from Li et al. [5]
Brick	1.5×10^{-5} kg·m^{-3}	Estimated from Li et al. [5]
Steel	6.6×10^{-3} kg·m^{-3}	Estimated from Li et al. [5]
Cast iron	2.8×10^{-5} kg·m^{-3}	Estimated from Li et al. [5]
Copper	1.9×10^{-4} kg·m^{-3}	Estimated from Li et al. [5]
Aluminum	1.4×10^{-4} kg·m^{-3}	Estimated from Li et al. [5]
Energy	1.9×10^{-1} kW·h·m^{-3}	Estimated from Li et al. [5]

Table S11
Inventory for mixed sewage effluent discharged into the sea from Beijing via 270 km of canal, assuming a 100-year lifetime for construction and a 40-year lifetime for the pumping station (unit is based on water flow transported).

	Input values	Sources
Cement	2.6×10^{-2} kg·m^{-3}	Estimated from Li et al. [5]
Gravel	8.4×10^{-2} kg·m^{-3}	Estimated from Li et al. [5]
Sand	3.7×10^{-2} kg·m^{-3}	Estimated from Li et al. [5]
Brick	1.5×10^{-5} kg·m^{-3}	Estimated from Li et al. [5]
Steel	6.6×10^{-3} kg·m^{-3}	Estimated from Li et al. [5]
Cast iron	1.4×10^{-5} kg·m^{-3}	Estimated from Li et al. [5]
Copper	9.5×10^{-5} kg·m^{-3}	Estimated from Li et al. [5]
Aluminum	7.1×10^{-5} kg·m^{-3}	Estimated from Li et al. [5]
Energy	1.9×10^{-1} kW·h·m^{-3}	Estimated from Li et al. [5]

Table S12
Examples of water-stressed cities with high population densities.

Cities	Seaside distance (km)	Effective population density (persons·km^{-2})	Year	Reference for effective population density
Ningbo (urban area), China	20	7 000	2015	[19]
Fuzhou (urban area), China	40	14 000	2011	[20]
Lianyungang (urban area), China	25	15 000	2011	[21]
Macau, China	0	19 000	2013	[22]
Tokyo Metropolis, Japan	0	6 200	2015	[23]
Singapore	0	8 000	2014	[24]
Chennai metrocity, India	0	17 000	2011	[25]
Mumbai metropolis, India	0	21 000	2011	[26]
L'Hospitalet de Llobregat City, Spain	0	20 000	2014	[27]
New York City, USA	0	11 000	2014	[28]

The distance between the urban area and the seaside is calculated using Google Maps.

Inventory analysis and method

1. Water treatment works

During water treatment, raw water is dosed with chemicals for coagulation and flocculation, passed through clarifiers for the sedimentation of particles, filtered using sand and anthracite, and finally disinfected with chlorine before being delivered to users [1]. The lifetime for waterworks was defined as 50 years [29], and both the construction and operation inputs were accounted for, as shown in Table S6.

2. Freshwater, wastewater reclamation, seawater distribution, and sewage collection systems

In Hong Kong, it is difficult to access the construction inputs for pipe systems. However, pipeline construction is ineligible for the urban water system. Therefore, the literature data were applied as inputs for the construction estimation for Hong Kong. The pipelines are significantly affected by population density [29,30]. The per capita length decreases as density increases due to greater utilization of pipe systems per capita. The relationship between population density and pipeline length is estimated by Eq. (S1) [30]:

$$y = 74.761x^{-0.8231} \tag{S1}$$

where, y is the per capita pipeline length (m·cap^{-1}) and x is the population density (persons·ha^{-1}). For example, the water distribution and sewage collection inputs for Hong Kong can be converted from the known information in Iasi City (IC), Romania, with Eq. (S2) [11]:

$$y_{\mathrm{HK}} / y_{\mathrm{IC}} = x_{\mathrm{HK}}^{-0.8231} / x_{\mathrm{IC}}^{-0.8231} \tag{S2}$$

The effective population density in IC was 3092 persons·km^{-2} in 2011 [11,31]. The inputs form a linear relationship with pipe length. The impact of water flow is not considered, because the pipe thickness increases with the pipe diameter in a linear relationship [32].

$$T = aD \tag{S3}$$

$$Q = \pi D^2 v / 4 \tag{S4}$$

$$\text{The area of material} = TD = aD^2 = 4aQ/(\pi v) \tag{S5}$$

where, T is thickness; a is a constant coefficient for different pipe diameters; D is diameter; Q is water flow; and v is water flow velocity.

These parameters are assumed to be the same in different scenarios. The unit function for construction inputs of the pipelines is in pipe materials per cubic meter, so the water flow is offset from Eq. (S5) and the inputs only relate to the water flow velocity. The water pipelines, wastewater reclamation pipelines, and freshwater sewage pipelines were all considered to have a lifetime of 50 years, while the seawater toilet flushing pipelines were given a lifetime of 20 years because of salinity corrosion [29]. The lifetime for mixed sewage collection pipelines was set at 40 years based on the lower salinity in saline sewage than in pure seawater. The detailed inputs for pipelines for Hong Kong are given in Table S7.

The same method was used for estimating the inputs for cities with different effective population densities, and ±15% uncertainty was considered.

3. CASP and the advanced SANI process

The conventional activated sludge process (CASP) is a typical wastewater treatment process that is widely applied. Organic matter is decomposed by microorganisms in the biological treatment process. In Hong Kong, sewage is mixed with seawater after toilet flushing. Despite the relatively high salinity of the mixed sewage, experience from operation and previous studies have shown that the salinity has no significant negative effects on the performance of CASP or on anaerobic sludge digestion. Therefore, the same chemical and energy consumptions in operation phases were considered for freshwater sewage treatment and mixed seawater sewage treatment, although the construction lifetime was assumed to be 40 years for mixed sewage treatment because of salinity corrosion and 50 years for freshwater sewage treatment [33].

The sulfate reduction, autotrophic denitrification, and nitrification integrated (SANI) process for wastewater treatment was developed based on seawater for toilet flushing (SWTF). SANI involves three major reactors: an anaerobic reactor for sulfate reduction, an anoxic reactor for autotrophic denitrification, and an aerobic reactor for ammonia oxidation. Sulfate originating from seawater acts as the electron carrier to oxidize organic carbon to carbon dioxide (CO_2) through sulfate reduction in the anaerobic reactor. Dissolved sulfide produced in the anaerobic reactor is subsequently used to denitrify nitrate in the anoxic reactor via autotrophic denitrification. In the aerobic reactor, ammonia in the wastewater is oxidized to nitrate by nitrifiers, and then recycled back to the anoxic reactor. The SANI® construction phase was assumed to be the same as that of CASP. Chemicals and energy requirements for operation based on previous studies are shown in Table S8 [15,16,34,35]. Wastewater was considered to be equal to 80% of the total water supply [13,36].

4. Calculations for the long-distance importation canal

The inputs for long-distance importation were estimated from the South-to-North Water Diversion Project (SNWDP) [5]. The impact of water flow on construction was excluded for a similar reason to that for domestic pipelines. The inputs are significantly affected by the diversion distance, as shown in Eq. (S6):

$$I_{\mathrm{My}}/I_{\mathrm{SNWDP}} = L_{\mathrm{My}}/L_{\mathrm{SNWDP}} \tag{S6}$$

where, I is input data and L is distance. All the calculations were based on SNWDP data. The freshwater canal lifetime was set at 100 years [5]. The inputs for freshwater imported from Miyun Reservoir (My) were estimated as shown in Table S9.

The materials for the seawater importation canal (cement, sand, gravel, and brick) were considered as having the same lifetime as those of the freshwater canal (100 years). Considering that seawater is more corrosive to metal, the lifetime of a pumping phase for seawater was considered to be 20 years. Table S10 presents the inputs for seawater transported from the seaside to Beijing. Considering the lower salinity in the mixed sewage effluent in SWTF scenarios, the lifetime of a pumping station was set at 40 years. Table S11 indicates the inventory for effluent discharged into the sea. In addition, a ±15% uncertainty was considered in this method.

5. Calculations for desalinated water importation pipes

For non-coastal cities that plan to apply seawater desalination for water supplementation, long pipes are needed instead of a canal in order to keep the water clean during transportation. Cast-iron pipes were considered because they are widely used for water supply and come in large diameters. The calculation was based on Eq. (S5). A cast-iron pipe with a diameter of 380 mm has a material mass of 76 $\mathrm{kg \cdot m^{-1}}$ [37], which was set as the comparison example for calculation. The lifetime of the cast-iron pipe was set at 50 years. The material consumption per cubic meter was calculated to be 2.8×10^{-7} $\mathrm{kg \cdot m^{-1}}$ within the serving lifetime.

For the energy consumption during the importation of desalinated water, please refer to the calculation for the long-distance importation canal.

6. Inputs for seawater desalination with reverse osmosis, wastewater reclamation, and energy analysis

The input data for seawater desalination with reverse osmosis (RO) and a nanofiltration plant were obtained from Refs. [38] and [39], respectively. The facilities for water treatment, wastewater treatment, wastewater reclamation, and the desalination process in this study were considered to be the same, even in different scenarios. Domestic pipelines, water importation pipes, and wastewater discharging pipes were calculated depending on the cities' geographic conditions. The energy used in this study followed the current situation in Hong Kong; that is, 53% hard coal, 23% nuclear, 22% natural gas, and 2% oil [40].

7. Method for sensitivity study and general model

The method for the sensitivity study is to consider the worst-case scenario for SWTF application, which is when the population density is low, the distance from the coast is great, the freshwater importing distance is also great, the ratio of water used for toilet flushing to total water consumption is low, and freshwater is readily available. More specifically, the effective population density was set at

3000 persons·km^{-2}. (Qingdao had an effective population of 4000 persons·km^{-2}.) The distance from the coast was 300 km. (The length of the intake pipe from Caofeidian, Tianjin to Beijing for the seawater desalination project was 270 km.) The freshwater importing distance was 70 km (the shortest distance for freshwater importation in Hong Kong and Shenzhen). Toilet flushing accounted for 20% of the total water consumption (as in Hong Kong and Shenzhen). Considering the freshwater shortage and vulnerable groundwater sources, only 70% of local freshwater availability was estimated.

According to the sensitivity analysis results, the most sensitive factors were determined. The co-relationship of the factors was revealed by fixing the insignificant factors at the worst conditions, as mentioned above.

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