Urban metabolic system of water for the 21st century

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Abstract Since human activity is about to outgrow the natural capacity, thus becoming a prominent affector to the environment, an urban/regional water system that minimizes influence on the environment, but at the same time, satisfies the human needs must be considered. This is necessary to keep well being urban/industrial areas side-by-side with the external nature. To address this problem, new systems of water and wastewater treatment as well as new methods of water utilization are coming up. The considerations and issues related to the planning and design of such water systems are discussed in this paper.

Keywords Water metabolism; human activity; urban environment; water systems; water reuse

New water metabolic system on quality utilization concept

Changing of paradigm
Up until now, there were individual goals for the water supply system and the sewerage system, respectively. The goal of the water supply system was to “provide clean water abundantly and inexpensively,” and the goal of the sewage works was to “promote sanitation and development of cities, and contribute to conserve aquatic environment of receiving basin.” In a separately driven urban system, there were no clear amalgamating philosophy or practical organization to express the fact that both are consisting of a series of bypasses to the natural hydrological cycle and supported by the main cycle simultaneously.

Such conventional system originated from the potential understanding that existed within a framework of small human community living comfortably in a rich environment fostered by an abundant nature, where individual demands of human activity were capable of being linked to the environment (nature). Now that the human activity is about to outgrow the natural capacity, becoming a prominent affector to the environment, we must consider an urban / regional water system that will minimize the influence on the environment, but at the same time, satisfy the human needs.

New paradigm
The urban / regional water metabolic system of the next era will be designed to “supply optimum quality of water for specific usages with only necessary amount for that use “through” appropriate integrated systematic use and recycle of water resources at a minimum cost (energy-consumption rate)” with the technological and managerial goal that “the cities and regions involved in water usage and drainage (water metabolism) should take direct and proper responsibilities over the water environment.” We must graduate from the conventional, rather coarse, urban water system that supplies top quality water en bloc for every purpose (water supply system), and then disposes of the used water again en bloc as “sewage.” To turn our way to establish an integrated and qualitative-concept-driven urban aquatic metabolic system from the conventional modern quantitative and rather independent water and wastewater system, it will take at least half a century. We are standing at the starting point of creating a new post-modern urban water metabolic system “with a comprehensive view on the needs of clever citizens and the global environment.”
Special position of human beings in our environment

We must consider the fact that “human beings, said to account as much as 25% of total animal mass on the ground surface of the earth with their cattle having a little greater amount than themselves, are not one element of the global eco-system that may simply co-exist in a commonsense term with other natural living beings”. However, “they are also an animal group which has to co-exist with other living things, and creating a unique standing space with excessively high energy and resource consumption rates, floating on the sea of various natural ecosystems.” Thus, in considering metabolisms performed by human beings, it is not sufficient to consider the typical metabolic chain (or network) that mutually take place among the groups of living beings in the natural ecosystem. We must “clearly define and establish the boundaries between human activity area and the natural world, minimizing the environmental load that arises through the open metabolism between the urban / industrial areas and the natural systems. Inside those boundaries (cities, for example) we must use materials and energy qualitatively depending on the purpose, and establish a similar genuine structure to those of other living things where an appropriate physiological cycle circuit is activated at a minimum energy-consumption rate.” We must consider “a composite urban metabolic system that will cause the least disturbance to the natural cycle of organic and inorganic matters,” to keep urban/industrial areas in a state of well being side-by-side with the external nature. Cities provide spaces similar to the animal body systems, managed through high rate consumption of low-entropy energy, high-quality ones such as electricity and petroleum, with tactfully integrated inside recycle systems, and running on open material / heat metabolism with the external environment through strictly controlled boundaries with the least amount of exchange. The existing conditions in the cities differ significantly from the general cycle type of natural ecosystem, which respects multi-stage cascaded utilization of the most valid energy and materials in the diversified ecosystem chains under the solar energy’s flux on the Earth’s surface.

Physiological system and membrane separation

The water inside the human body transports substances and heat, and is disposed from the body after it has been recycled and reused about twenty times. This means that about 5% of the amount of water inside the body must be replenished with fresh water supplied from outside the body. Water acts as the intermediary for transferring heat and substances inside the body, connecting the circulatory systems and the individual parts in the living body. These activities are mainly supported by organs using appropriate separation through biological membranes, operating on high-quality biochemical energy and accompanied by biological chemical reactions in most cases. At the end of the 20th century, we obtained the mass-producible technology to design and manufacture various kinds of separation membrane to meet engineering requirements. In civil engineering terms, urban / regional water metabolic engineering enabled to exchange major tool of impurity separation from the ecological processing technology, i.e. precipitation/sedimentation/filtration, biological treatment process, etc., that have been supporting society for over 200 years to new physiological processing technology, i.e. membrane separation. In the coming post-modern era, Micro/ultra/nano-membrane separation technology accompanied by the necessary chemical/biochemical/physical reaction will become a core to quality-based multi-stage water utilization, and to recycle technology within the high-density society. The rapid filtration system and the biological wastewater treatment systems have been universalized in the early 20th century as a cornerstone to water and wastewater system, used widely for hundred years. Since then, it is the first time in about 100 years that a more new basic technology – membrane separation – for water treatment has emerged for use for in new aquatic metabolic system design.
We have just begun the study on new methods of water utilization. In the typical modern industry, we indulgently obtained good-quality resources from Mother Nature to suit our individual purposes. We did not hesitate to use high-quality water resources to manufacture profitable products at one’s discretion, expecting that the waste-processing technologies in the downstream activity (vein industry) would somehow take care of the generated waste. It was typical for two separate technologies to exist in the physical infrastructure of modern society; one in the upstream regions for obtaining resources to earn profits or benefits, and the other in the downstream regions for treating up the remains. Under the new water system, it will be necessary to determine whether the water should be used through that particular method for that specific purpose, taking into factor the difficulties of recovering quality, and the extent of value gained from utilization of that quality. At the same time, we must design stable and the minimum energy-consuming systems for water supply / disposal, and recycling between the two. The system will be contrived into a comprehensive system, taking into account the related issues, possible alternative methods, resource and energy consumption rates and complexity of information system for design / management, and shall become fully developed within several decades.

General situation of the day
At this present stage, there are still no definite movements to link and to handle comprehensively the industry (living) activities and the resource systems as mentioned above. Although speaking of the global environment era, we have not yet to begin redesigning our civilization in a specific sense. It may not be easy for the water system to stand out alone in this movement. However, public water systems require continuous long-term investment before they may become functional as a comprehensive social infrastructure system. Therefore, unless we direct our investments to point toward the future structure now, we will be facing an intolerable difficulty in the future. We must at least transform the water system so as to clearly support the concept that the essence of water utilization is the utilization of quality. Regarding this point, the idea behind the structure that the author has introduced (Tambo, 1976) 25 years ago remains basically unchanged. The word “urban water metabolism” that the author used for the first time in the paper is now becoming a universal term. However, it is regrettable that the word is not used in a clearly defined context that includes the above description.

The way to new urban / regional water metabolic system

First step
Water that demands the physiological safety of human beings is taken in selected amounts from strictly managed water conservation areas in the upstream basin of the hydrological cycle, and treated by appropriate processing, supplied as drinking water through exclusive water (potable water) supply systems made of high-quality materials. Water not intended for drinking accounts for the majority of the water demand, and can be taken from downstream areas, from rivers and impoundments with much larger catchment areas, close to the water-utilization point. Reclaimed and recycled sewage waters that have been treated through advanced process-trains will be added to these river waters as needed, and provided through the general water supply system converted from the present (whole service) water supply systems.

The exclusive water supply systems for drinking waters (drinking water supply) that receive water from strictly conserved limited upstream water collecting basin free from most man-induced pollution, will only require minimal water processing, without advanced water quality testing which itself does not add any real value. While a new
exclusive drinking water supply system is being installed, a small pipe network for supplying high-quality drinking water will be attached to the end of the present water distribution network block, and nano-membrane filtration equipment for upgrading purpose is attached to the intake point of the drinking water service block.

About 10% of high-quality water is filtered through the membrane installed at the inlet of the service block and taken in by the pressure from the main distribution networks. With the attachment of a small water pump after the membrane, the drinking water service branches supply high quality drinking water to individual houses. The substances rejected by the filter increase the concentration of the remaining 90% of the water originally in the distribution pipe, about 1.1 times. However, this will not be a problem for water intended for purposes other than drinking. The high-quality water service network (block) is connected gradually by new drinking water distribution main, completing a consistent dual-water supply system covering from water distribution to service system. The water supply should not be cut off during a drought as we have experienced often, but the ratio of processed sewage water treated through advanced system to be added to the non-drinking water in the dual water supply system.

Recently, some have viewed seawater as an unlimited source of water, and consider maintaining the present urban water system by increasing the amount of water supply through desalinated water. This method will immediately speed up high-energy consumption, turning away from the global environment era. Simultaneously, under the present technology, for all freshwater gained, the same amount of waste brine must be disposed of. By taking such measures that prolong the life of the conventional system, we would destroy any new efforts toward creation of a new urban water system that should be based on the basic understanding that the essence of water utilization is the utilization of quality. It will stop the evolution toward improved urban / water environment system into the post-modern era, when cities and the natural water environment must coexist at the responsibility of the cities.

Water district

Here is an example of the possible structure that may be introduced in an effort to clarify the responsibilities of cities within the ecosystem chain when they attempt to possess a dual or multiple water supply system and move toward a more closed cycle, and establish a water environment district (a water metabolic space where cities take autonomous responsibility within the hydrological cycle) with a clear boundary drawn between the conservation area (natural system) and the controlled area (urban system) in the basin of high degree of activity, and high population density.

The objectives for developing such a system may be: (1) to draw a clear distinction between the water environments that should be conserved, and those to be utilized, as well as to clearly define the conditions for joining the two in maintaining good nature in the conserved areas; (2) to enforce control only at the borders within the latter, and/or only inside the urban control areas; (3) to have a clear awareness within the controlled area (inside the cities) of the fact that essential factor behind water utilization is water quality consumption, to keep in mind multi-stage water utilization, to minimize and to take care in the recycle of water that require additional energy consumption; (4) to limit areas as much as possible, and to stop unlimited spreading of water metabolism, keeping the metabolic structure within the boundaries for which cities are capable of being responsible; and (5) to not let the increasing density of activity within the boundaries affect the external environment.

In order to realize the two goals of limiting space and preventing an increase in energy consumption, and to visualize the 21st-century dream of sustaining an “ideal” natural water environment, excellent scientific operations are certainly important, but stepping away
from being an engineer, contemplating from a different perspective, walking the rivers to
learn about the rivers themselves, and thinking about what needs to be considered to correct
the fundamental existence of human beings, which have grown too prevailing, may equally
be important.

Additional remarks
In Japan, water demand is increasing only in the cities. The rivers are still laden with serious
problems concerning water quality and quantity as well. Food production is where the most
water is required. There have been discussions concerning agricultural chemicals, eutro-
phication by fertilizer and a shift from agricultural water use to urban water use. Japan
decreased the number of its paddy fields, and imports 3 million tons of grain per year from
various countries. The self-sufficiency rate for food is thought to be much lower than 45%.
About 1,000 tons of water is needed to produce 1 ton of grain. In the case of paddy rice,
2,000 tons is needed. This implies that we are importing 30 billion tons of water per year in
the form of grains. This type of water can be called “green water.” It is half the annual
demand of water for agricultural use, and is approximately equal to the annual demands of
urban use and industrial use in Japan. If we set out to raise our self-sufficiency rate for food
with the purpose of strengthening the national security of our people in our future, a major
problem on water resource will arise immediately. The trinity of discussions on creation
of an independent urban water metabolic system, a stronger tie between the agricultural
system, and the conservation of environment should be held upon adequately assigning of
various water metabolic systems along the rout of the hydrological cycle. We must start
various integrated studies including the World Trade Organization debate on agricultural
trade, forecast on energy supply, maintaining health of ecosystem, and the safety and con-
venience of human beings.

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