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Japan Education Center of Environmental Sanitation

Status of Onsite-treatment of Domestic Wastewater Management in Japan

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INTRODUCTION

Water is cultivated by precipitation and flows down the ground surface, and then becomes available water resources. During the processes to water resources, water dissolves and carries various kinds of impurities. There is an acceptable level of impurities for each purpose of water use. Water plays a variety of roles in order to sustain environmental ecological systems; therefore, it is necessary to show the level that ensures not to cause any hazard, whether to human bodies or to particular purpose of water use.

The water resources that are supported by the water cycle are limited, and the water resources per person are ever decreasing due to the population growth on the Earth. Therefore, the proper watershed management on water quality and quantity control is essential to use the limited water resources efficiently.

Natural water body has self-purification capacity that can reduce the adverse effect of pollutants. However, its capacity is very much limited; therefore, it is necessary to control the pollutant loads to water bodies.

The appropriate technology of water supply and sanitation is dependent on the climatic, economic and cultural characteristics of the project site. The first target of water supply and sanitation technology is to reduce the potential risks of waterborne infectious diseases. Most of pathogens in water are associated with suspended particles; therefore, the train of treatment units should have a solid-liquid separation process followed by a disinfection process. The water supply system should be developed together with sanitation system because most of the pathogens in living environment are related to the excreta. The selection of sanitation system of on-site treatment or off-site treatment is heavily dependent on the economical potential of the project site. In order to develop an appropriate sanitation system, the effect of treated wastewater to the receiving water body as well as the conjunctive use of water resources must be considered. But the affordability and sustainability of the sanitation facilities are often much more crucial for choosing an option.

There are several domestic wastewater management systems, and Japanese government has promoted to apply not only public sewerage system but also on-site wastewater treatment system. The on-site treatment system, so called Johkasou system, which is developed in Japan, is a unique, sophisticated and cost-effective system for managing domestic wastewater. In order to get public recognition to it, there was a series of discussion among the stakeholders. In other words, there are backgrounds of social, natural, economic and technological development. Here, this paper deals with the history of sanitation system and Johkasou system, and issues to promote the Johkasou system in order to provide the information for selecting appropriate technology for domestic wastewater treatment.

HISTORICAL BRIEF ON HUMAN EXCRETA HANDLING

Water-based sanitation facilities, as is understood today as the sanitation itself, was developed in the middle of nineteenth century. Prior to the development, the sanitation practice differed between regions or hierarchies, and the archaeological remains date back to several thousand years. Public buildings in Greco-Roman Era were already equipped with public latrines, and the city had storm drain infrastructure. Similar findings have been identified in many part of the world, i.e. Babylonia, Palestine, Indus, etc.; however, it is probable that the majority of the people then defecated on streets, in fields, and/or along rivers.

Until the end of Middle Ages, no significant development on sanitation facilities had been done. Open defecation and bedpan defecation were still principal ways for ordinary people, and therefore, epidemic diseases prevailed periodically over many cities in concordance with population growth.

Nineteenth century was a turning era in terms of sanitary systems. First water closet was connected to water and wastewater lines in 1850s in London. Earth closet and dry toilet with urine/feces separation also appeared in this period, but these non-water systems eventually disappeared and water closet has propagated throughout the world.

In Japan, people once lived in a rice-based agricultural society. The Japanese government closed the door to foreign countries and limited foreign trade and communication during Edo Era from 1600 to 1860. Thus, Japan was fortuned to be escaped from the communicable diseases such as cholera and typhoid fever; therefore, night soil was not acting the agents for transmitting such severe communicable diseases. Instead, night soil was used for valuable fertilizer to increase the yield of foodstuff for meeting the population growth in the country. The entire households provided vault toilets to store the night soil. Farmers collected night soil from households in urban areas in exchange with agricultural products. Therefore, the Japanese toilet system was traditionally dry system that did not use any water for anal cleansing and stored night soil in the vault under the stool because night soil was used for valuable fertilizer. In this way, people for ages managed to dispose night soil in harmony with the ecosystem.

The drastic change in Japan's industrial structure after World War II, notably the rapid industrialization; however, resulted in the concentration of population in large cities. The trends in the area of densely inhabited districts (DID-area where population density is 4,000/km^2 or more, or with 5,000 inhabitants in the town area), population and the population density in those areas are shown in Figure 1. The population increase and decrease by the size of city from 1955 to 1975 is shown in Figure 2. It can be understood from these chronological data that urbanization and population shift to urban area have rapidly progressed as other countries have experienced in general. The increase of the total population in that period has been absorbed by the expansion of DID. The population in DID in 1996 was approximately eighty millions, nearly 65 percent of the total population, and became 1.5 times of that in 1960. As shown in Figure 1, the population density of DID is going to decrease, and as a result, the peripheral suburbs of those areas have been developed as residential areas for the people who emigrate from densely populated areas.

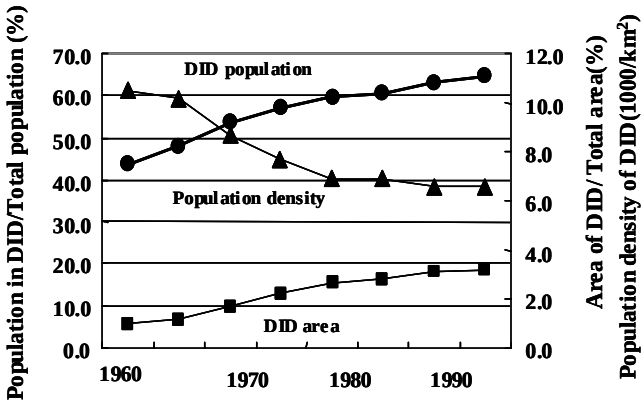

Figure 1 The trends of densely inhabited area (DID) in Japan

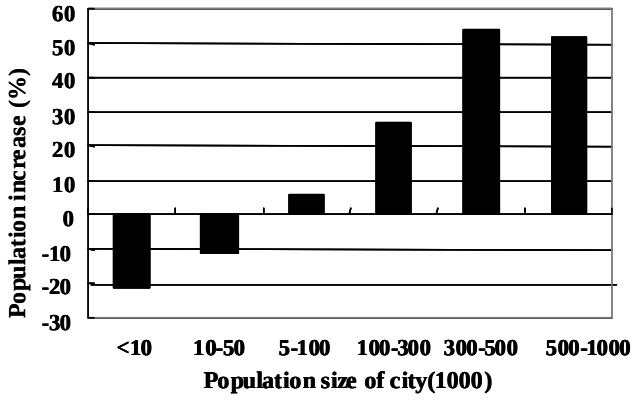

Figure 2 Population increase from 1955 to 1975

The domestic population migration from rural areas to urban areas, as the result of industrial conversion from agricultural industry to manufacturing and/or service industry, decreased the number of commercial farm households as shown in Figure 3. Although the number of the commercial farms decreased, the government kept the policy that the Japanese staple food, rice, should be supplied by domestic production. The

decrease of fulltime commercial farm households brought changes in traditional agricultural style; in which natural material such as matured human excreta were used as fertilizer. Today, modern agriculture becomes dependent on chemical fertilizer as shown in the Figure 4.

The population growth in urban areas and the poor public services and infrastructure caused serious public health conditions after World War II. In 1960s, the numbers of infectious diseases transmitted by faecal-oral route were raging about 100,000 cases of shigellosis and 6,000 cases of poliomyelitis a year, as shown in Figure 5.

In order to cope with such serious public health conditions, the Japanese Constitution adopted in 1947 states that the government has to improve public health to ensure the dignity of the citizen. Based on the Constitution, numbers of laws relating public health promotion were established in 1950s. Waste and Public Cleansing Law and Waterworks Law were also set to improve environmental health conditions, and based on these laws public water supply facilities and night soil treatment facilities have developed throughout the countries as shown in Figure 6. The development of public sewage system has not been enhanced due to the financial constraints on those decades. However, night soil treatment facilities that treat the collected night soil from vault toilets by vacuum trucks have selected an appropriate system for managing night soil that used to be managed by agriculture sectors as a valuable fertilizer. By the development of safe water supply and sanitary treatment of night soil, the occurrence of infectious disease transmitted by faecal-oral route was drastically decreased as shown in Figure 5.

Japan's unique system for treatment of night soil was developed under the conditions as described above. However, the wet flushing toilets were spread rapidly in 1970s when the demand for it heightened strongly with the modernization of citizen's life. This owes the development of mass production technologies of on-site night soil treatment tank, hereafter Johkasou, using fiberglass reinforced plastic (FRP) and the establishment of structural standards of Johkasou system laid down by the Building Standards Law enacted in 1969. As a result, sewage system and Johkasou system have spread side by side as shown in Figure 7.

Johkasou system is rather sophisticated technologically because not only anaerobic and/or aerobic biological processes but also a

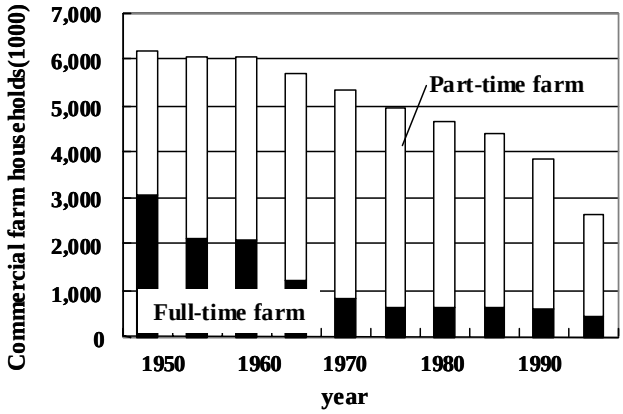

Figure 3 Trends of the number of commercial farm households

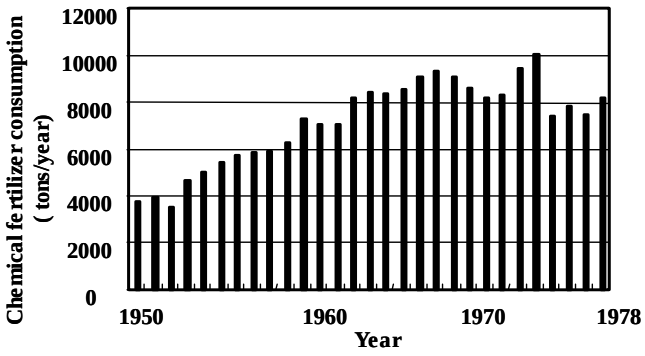

Figure 4 The consumption of chemical fertilizer in Japan

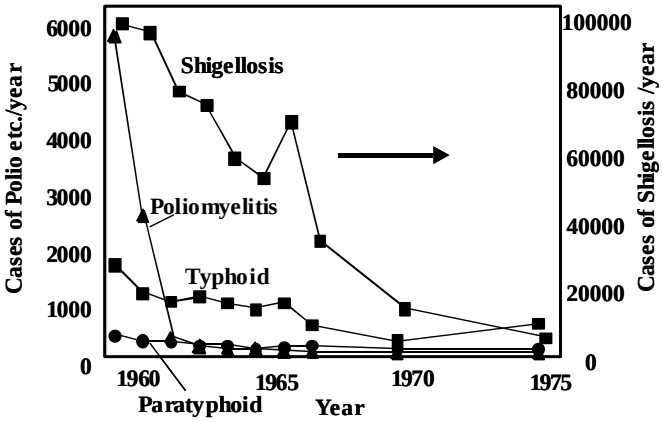

Figure 5 Trends of infectious diseases

disinfection process is applied. In the earlier stage, Johkasou can treat flush toilet wastewater only, not capable of treating gray water (domestic waste water exclusive of night soil). Such Johkasou system is called "Tandoku-shori Johkasou" in Japanese terminology. "Tandoku" means sole or separate and "shori" means treatment. Although flush toilets using Tandoku-shori Johkasou are prevailing to dry toilet system, the night soil treatment plant used for sanitary treatment of sludge from Johkasou. By one way or another, every citizen can access to sanitary treatment of night soil, and the population who use water flush toilet has reached to 85 percent by the development of Johkasou and public sewage system. However, the population who discharges the gray water without treatment is remaining about 40 percent in 2000.

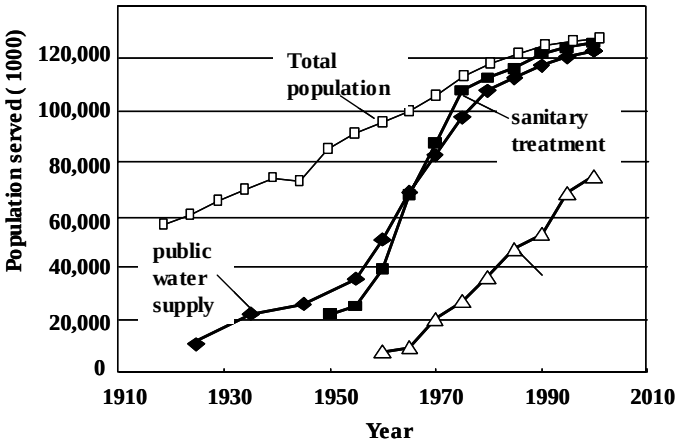

Figure 6 Development of water supply and sanitation

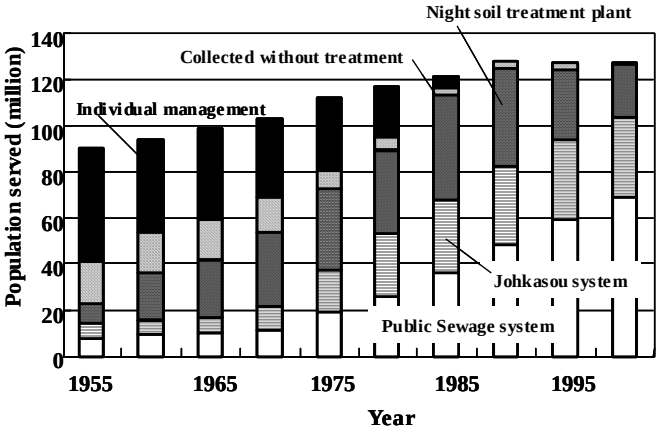

Figure 7 Development of domestic wastewater management

No satisfactory improvement in the quality of natural water resources was made even with the strict control of industrial wastewater. It was recognized that the direct discharge of untreated gray water was the major cause of water pollution of public water bodies. This gave rise to the need for new Johkasou system that are capable of treating gray water, as well as flush toilet wastewater. The driving force standards for Johkasou system were enforced in 1980. By the new standards, Tandoku-shori Johkasou system could still be used for treatment of domestic flush toilet wastewater continuously, and a new Johkasou system that can treat whole domestic wastewater. The system is called "Gappei-shori Johkasou" which means combined treatment in Japanese terminology.

SELECTING APPROPRIATE DOMESTIC WASTEWATER MANAGEMENT SYSTEM

Discharging domestic wastewater into water bodies without treatment causes various adverse effects to irrigation, drinking water, industrial water, groundwater, environmental water, etc. The extent of the effects should be evaluated in relation to the environmental capacity defined by self-purification which natural ecosystem itself owns (Figure 8). The quality and quantity of domestic wastewater are influenced not only by the living standard, i.e. water consumption and the use of water flush toilet, but also by population and population density. The effects of quality and quantity of domestic wastewater vary between the types of settlements. In other words, the effects are different between urban areas and peripherals, if the wastewater load has seasonal fluctuation as in tourist sites or not, or between the places with insufficient water resource to dilute pollutants and agricultural areas with sufficient water body. Further, the effects of domestic wastewater are also dependent on the types of water usage such as irrigation, which should be evaluated by nutrients (nitrogen and phosphorus), or drinking water, which must be evaluated by pathogenic microorganisms or precursors of trihalomethane. Therefore, the system for domestic wastewater treatment must be selected with elaborate consideration of the place in question, and it should not be applied such a simple rules as sewerage for urban, Johkasou for peripheral, or dry toilet for rural.

Since public sewage systems have other purposes such as flood control by discharging rainwater in urban areas and it is considerably difficult to secure a number of sites for many small communal sewage

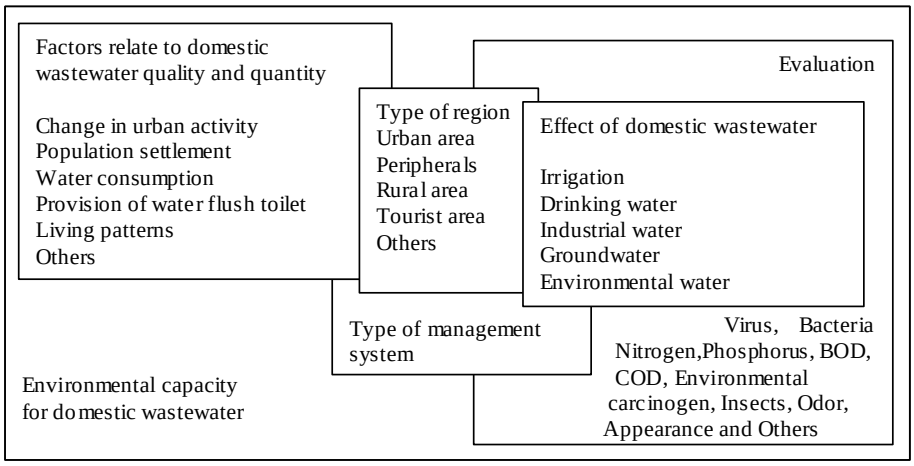

Figure 8 Factors relating with domestic wastewater management

treatment plants in urban areas, the provision of sewer system in DID area is highly effective, while in small or low-density areas are less effective due to fewer beneficiaries of sewerage construction. The reason for which public sewage system are being selected in existing urban areas is that it is difficult to secure sites for many small treatment plants within the urban areas in question.

Although most of local government have already authorized their sewage plans for DID, their implementation have been delayed in many cities. By contrast, Tandoku-shori Johkasou has spread considerably to fulfill peoples' demand for water flush toilet. Since streams in those area serves as a drainage system, streams have turned into like sewer, lost their amenity, caused foul odor, and resulted in an outbreak of unsanitary insects, etc., because of loose effluent water quality regulation on Tandoku-shori Johkasou and discharges of gray water without any treatment. The residents living in those areas have rallied in increasing numbers to campaign for resuscitation of water environments. The areas situated on periphery of DID that are excluded from any public sewage plan, are influenced by the life style of urban areas, consequently, the motivation of these people to install Johkasou is higher than that of pure rural areas. Water pollution of small streams and irrigation canals serving as drainage systems has caused mal-effects to agricultural activities and sometimes-serious problems to sources for drinking water.

The situation mentioned above is found in areas where domestic wastewater influences the water environment in those areas directly, however, it must also be reminded another type of adverse effect of domestic wastewater. That is regarded as a problem of the so-called up- and down-stream conflict, whereby a regional gap emerges in terms of "occurrence" and "influence". Thus, it is necessary to treat both problems in upstream small basins and those in downstream basins as multi-tiered problems, and to take comprehensive steps to cope with them.

While the spread of Tandoku-shori Johkasou served to improve peoples' life, the pollutants from Tandoku-shori Johkasou are now one of the major contributors of the total loads to the environmental water bodies because of its high organic load in the effluent. An assessment of contaminated water bodies has revealed that domestic wastewater accounts for a large portion of organic pollutants, up to 70 to 80 percent of the all-organic pollutants entering the Tokyo Bay (located on the south of the greater Tokyo Metropolitan area) and the Lake Teganuma (in the suburbs of Tokyo with rapid housing development) are originated from domestic effluent and the percentage is further progressing.

In the late 1970s, with the rapid spread of Johkasou system, there were strong social demands for ensuring proper installation, desludging, and inspection of Johkasou system, and request for government-approved specialists to carry out this kind of work in Japan. To cope with this situation, a law called the Johkasou Law was enacted in 1983.

The Johkasou Law stipulates systematized regulations for (1) the manufacture, installation, maintenance and desludging of Johkasou system, (2) the official registration of Johkasou installers and maintenance operators, (3) the license of Johkasou desludging agencies. As part of this legislation, the law stipulates national qualifications for people engaged in constructing and maintaining/operating Johkasou system in an effort to maintain a healthy living environment. The former are called "qualified Johkasou Installation

Workers" and the latter are called "qualified Johkasou operators".

This law triggered the spread of small-scale Gappei-shori Johkasou system for individual household, capable of discharging effluent with BOD of less than 20 mg/L.

At the same time, the ministry established a system of national subsidy to help people install the small-scale Gappei-shori Johkasou system. This system attracted the attention of municipal authorities and the public, resulting in a rapid spread of small-scale Gappei-shori Johkasou throughout Japan.

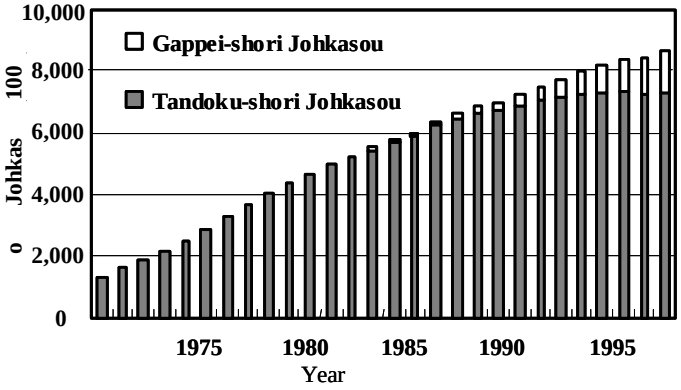

Figure 9 Development of Johkasou

Gappei-shori Johkasou system is effective in small towns and villages. Middle to large scale Gappei-shori Johkasou system has features similar to those of community plants, but small scale Gappei-shori Johkasou system offers some unique advantages, for example, they can be installed in individual houses without any topographic limitation and can discharge treated wastewater on the spot. Therefore, the proportion of Gappei-shori Johkasou is increasing year by year as shown in Figure 9.

CONCLUSIONS

There are several systems available for treating flush toilet wastewater and gray water. However, there is no universally applicable and suitable system. For example, modern sewage systems are neither effective nor efficient in rural areas even though they are efficient in large cities. This is because large capital investment and long construction period are required. An appropriate way must be chosen by considering various factors relating to the planned area such as geographical conditions, population density, the effects of facility installation, and the cost effectiveness.

Johkasou system either Gappei-shori Johkasou or Tandoku-shori Johkasou is a unique system for managing whole domestic wastewater or only night soil, respectively. Since Japanese toilet system was originally dry system for using night soil for fertilizer. However, the interest of night soil application to fertilizer was diminished by the popularization of chemical fertilizer. Then the collected night soil treatment system has developed in order to assure sanitary treatment of night soil. This dry toilet and collective night soil treatment system has been very much effective to control pathogens relating to night soil. The existence of the collected night soil treatment facilities which can accept and treat the sludge generated from Johkasou has helped the development of Johkasou system in Japan.

Johkasou system, especially Gappei-shori Johkasou, is one of the options to treat domestic wastewater by less investment cost than public sewerage system in peripheral area of large city and rural area. However, it is necessary to evaluate the technical characteristic, total cost and its resource, the condition of receiving water bodies and community understanding as well as willingness to pay for the system.

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BOD, Nitrogen and Phosphorous Removal Technology in Johkasou Systems

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INTRODUCTION

Johkasou system is a unique technology of domestic wastewater treatment. It is an alternative of the sewerage system in the regions where sewerage system cannot be introduced due to the economic and locational constraints. The use of johkasou system is spreading and the confidence in its performance is increasing greatly. Wastewater generated from household contains different types of organic pollutant represented by BOD concentration. There is also a serious problem of eutrophication of lakes and bays due to the contamination of nitrogen and phosphorous. A system that can remove nutrients such as nitrogen and phosphorous together with BOD is expected in the present era. To cope with these issues, an efficient, high quality johkasou system was developed in 1995, focusing mainly on removing nitrogen and phosphorous from domestic wastewater. Further research is going on for developing johkasou systems, which will be more efficient and easy maintenance.

Several original johkasou systems are introduced here, which are designed for removing BOD, nitrogen and phosphorous from domestic wastewater. It is expected that in the future demand for johkasou systems will be stronger, especially for johkasou systems with advanced treatment performance.

STRUCTURE AND TREATMENT PERFORMANCE OF JOHKASOU SYSTEMS

Structure of Johkasou Systems [1)]

The structure of johkasou system is designed according to the guidelines given in Structural Methods, stipulated by the Ministry of Land, Infrastructure and Transport. The structure of johkasou system is classified for different degree of treatment. It is designed as per the need and fabricated by the manufacturer based on the Structural Methods. Figure 1 shows a small-scale johkasou system designed for a single-family house of 5-10 equivalent persons. It consists of a capsule shaped tank made from plastic materials and is usually installed underground. Figure 2 shows a medium scale johkasou system, which is a standard on for treating wastewater generated by up to 50 equivalent persons. Large scale johkasou systems are used to treat wastewater generated by over 51 equivalent persons. The large scale johkasou systems consist the same capsule shaped tank made from plastic materials and also the tank made from concrete

Fig.1 Structure of a small-scale johkasou system

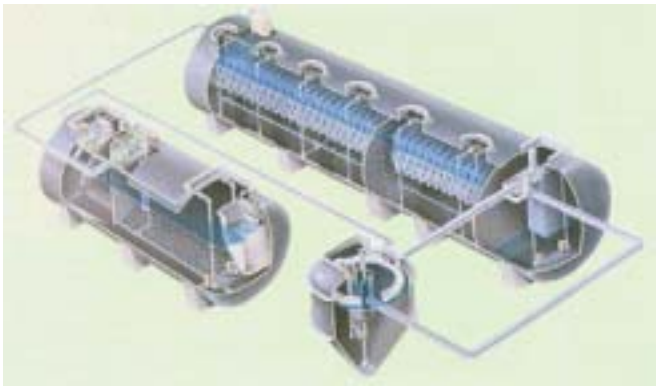

Fig.2 Structure of medium a scale johkasou system

structure. It is installed onsite as shown in figure 2. Various kinds of johkasou systems have been installed on site as per the demand. But the internal structure of the johkasou system is made on the basis of guidelines given in Structural Methods and divided into many parts according to the required volume of wastewater treatment.

Wastewater flow in Johkasou Systems and quality of treated water [1) 2)]

Domestic wastewater from toilets, bathrooms, kitchens and washing flows into a johkasou systems. Concentrations of BOD, nitrogen and phosphorous in domestic wastewater depend on the mode of inhabitant lifestyle and the purpose of building use. The domestic wastewater that flows into a johkasou system contains normally with concentrations of BOD 200 mg/L, nitrogen 50 mg/L, and phosphorous 5 mg/L. On the other hand, treated water quality from johkasou systems vary as per the guidelines given in the Structural Methods. Various levels of effluent quality is determined in the Structural Methods as BOD concentrations less than 60, 30, 20, and 10 (unit: mg/L), nitrogen concentrations less than20, 15, 10 (mg/L) and phosphorous concentrations less than 1 mg/L, respectively. However, nearly all of the newly installed johkasou systems are found to be ones capable of discharging effluent with BOD concentration less than 20 mg/L.

BOD, NITROGEN, AND PHOSPHOROUS REMOVAL TECHNOLOGY [2) - 4)]

Main Treatment Function of Johkasou Systems

Although there are many treatment methods in johkasou systems, a common treatment method is given in Table 1. Johkasou systems for BOD removal mainly apply the method given in row (3). In addition, the function of nitrogen and phosphorous removal is not included in this table. Nitrogen is removed by the addition of other biological process. The phosphorous is removed by adding physico-chemical process like flocculation sedimentation.

Table 1 Common treatment function of Johkasou Systems

Flow number	Main function	Unit equipment
(1)	Remove a large-sized solid materials (toilet paper , hair, etc) and sand in waste water	Screen, Grit chamber, Sedimentation-separation tank, Anaerobic filter tank
(2)	Remove of suspended solids by physical and biological process	Sedimentation-separation tank, Anaerobic filter tank
(3)	Remove BOD by the action of aerobic bacteria	Aeration tank, Contact aeration tank Trickling filter tank, Rotating biological contactor tank
(4)	Separate suspended solids, such as bacteria from treated water	Settling tank
(5)	Disinfection by chlorination	Disinfection tank
※	Sludge thickening, storage and disposal	Sludge thickener tank, Sludge storage tank, Sludge thickening-storage tank

BOD Removal

Table 1 shows the treatment processes for BOD removal by aerobic microorganisms in a biological treatment system. The bio-chemical reaction of BOD removal is given roughly in equation (3.2.1) - (3.2.3). The microorganisms consume organic matters for metabolism, synthesis and energy hence the organic matters in wastewater reduced, this decreases the BOD concentration. In addition, the treatment method using these principle are divided broadly into two types: fixed biofilm process, in which the microorganisms attach on the inert media; activated sludge process, in which the microorganisms suspend in the aerated mixed tank.

Figure 3 shows a flow sheet of the "anaerobic filter contact aeration process" mainly used for a

small-scale johkasou system. A flow sheet of "extended aeration process" is shown in Figure 4, and it mainly used for middle-scale johkasou systems which are similar to the activated sludge process. Both of the johkasou systems showing in Figure 3 and in Figure 4 are designed for removing BOD concentrations to less than 20 mg/L.

Oxidation of organic matter (Organic removal)

$$C_XH_YO_Z + O_2 \xrightarrow{\text{Microorganism}} CO_2 + H_2O + \text{Energy} \quad \cdots (3.2.1)$$

Synthesis of new cells (Excess sludge production)

$$C_XH_YO_Z + NH_3 + O_2 + \text{Energy} \xrightarrow{\text{Microorganism}} (C_5H_7NO_2) + CO_2 + H_2O \quad \cdots (3.2.2)$$

(Cell)

Self-oxidation of cells (Self decomposition of activated sludge)

$$(C_5H_7NO_2) + O_2 \xrightarrow{\text{Microorganism}} CO_2 + H_2O + NH_3 + \text{Energy} \quad \cdots (3.2.3)$$

(Cell)

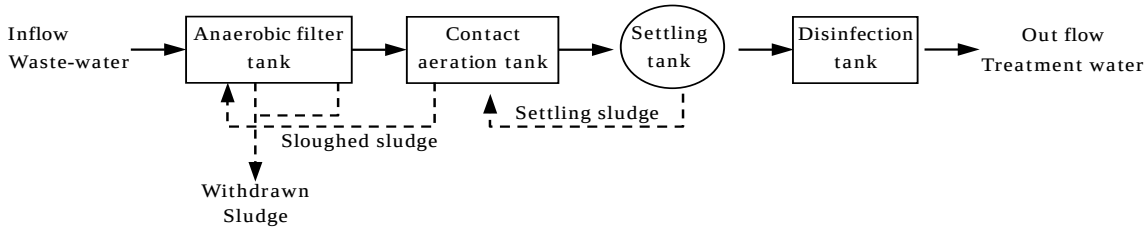

Fig.3 Flow sheet of the anaerobic filter contact aeration process

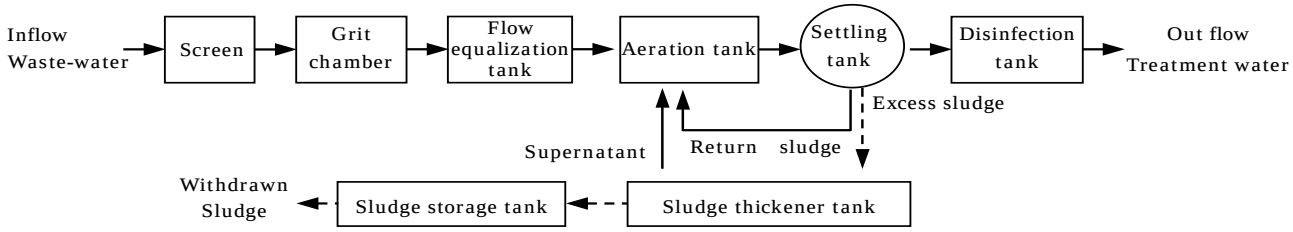

Fig.4 Flow sheet of extended aeration process

Nitrogen Removal

A johkasou system removes nitrogen according to biological methods in wastewater treatment system. The reaction of nitrogen removal is given roughly in equation (3.3.1) and (3.3.2). Moreover, the nitrification process performs in an aerobic condition while the denitrification takes place during an anaerobic or an anoxic condition. It consists of two processes called biological nitrification and denitrification.

Figure 5 shows a flow sheet of the denitrification type anaerobic filter contact aeration process. It is designed for both BOD and nitrogen removal to less than 20 mg/L. Figure 6 shows the flow sheet of the nitrified water recirculation type activated sludge process. The differences between the biofilm process and the activated sludge process will be recognized by comparing figure 5 and figure 6. Both processes apply the principle of recirculation nitrification and denitrification process. Both tanks, nitrified tank (Figure 5) and contact aeration tank (Figure 6) are kept in aerobic condition, and thus the ammonia contained in the wastewater got nitrified. This nitrate nitrogen recirculates as shown in denitrification type anaerobic filter tank (Figure 5) and denitrifiction tank (Figure 6) as mixed-solution (nitrified water). The BOD (organic matter) contained in the wastewater acts as a hydrogen donor for the denitrification bacteria living in the tank and convert nitrate into nitrogen gas, which is released to the atmosphere.

Nitrification (Nitrification of ammonium nitrogen in waste water)

Nitrification bacteria

$$NH_4^+ + 2O_2 \rightarrow NO_2^- + 2H^+ + H_2O \quad \cdots (3.3.1)$$

Denitrification (Conversion of nitrate nitrogen to nitrate gas)

Denitrification bacteria

$$2NO_3^- + 5(H_2) \rightarrow N_2\uparrow + 2OH^- + 4H_2O \quad \cdots (3.3.2)$$

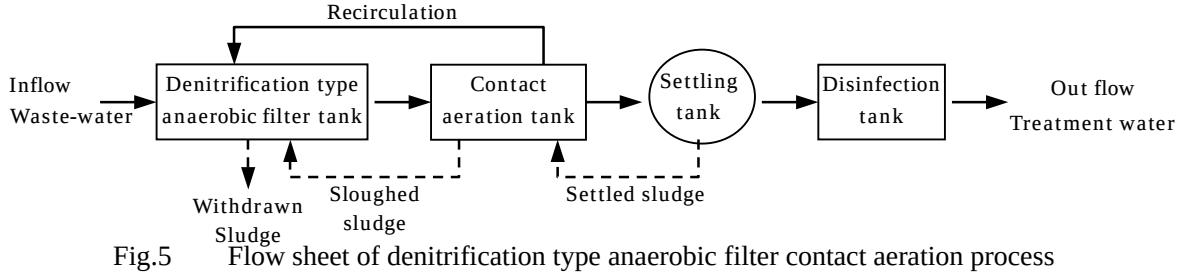

Fig.5 Flow sheet of denitrification type anaerobic filter contact aeration process

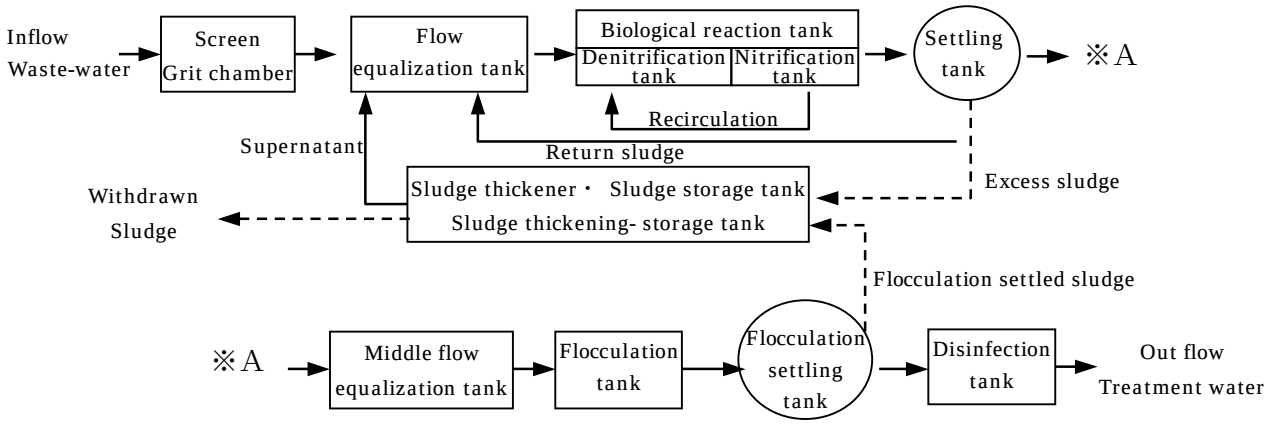

Fig.6 Flow sheet of nitrified water recirculation type activated sludge process

Phosphorous Removal

Physico-chemcial method, flocculation sedimentation is widely used for removal of phosphorous because of its simplicity, easy maintenance and treatment quality. The phosphorous removal process is already shown in figure 6, which consists of a equalization tank, a flocculation tank, a flocculation settling tank, and a sludge thickening and storage tank. The mechanism of phosphorous removal by flocculation sedimentation is given in equation (3.4.1) and (3.4.2). Based on chemical reaction, metal ion of coagulant reacts with phosphate ion in wastewater and produces precipitate of phosphate salt. Generally ferrous salt and aluminium salt is used as a coagulant.

However, this process of phosphorous removal has some demerits as it is expensive because of the high cost of flocculent and increase of sludge production, and also this method is not given in the guidelines of Structural Methods. Therefore, advanced wastewater treatment system of small-scale johkasou systems that has easy maintenance, operation and compact volume, is desired these days.

Flocculation reaction of phosphorous

$$M^{3+} + PO_4^{3-} \rightarrow MPO_4\downarrow \quad \cdots (3.4.1)$$

$$M^{3+} + 3HCO_3^- \rightarrow M(OH)_3 + 3CO_2 \quad \cdots (3.4.2)$$

(M=Fe, Al etc.)

NEW TREATMENT TECHNOLOGY OF JOHKASOU SYSTEMS

As described previously, johkasou systems are designed and manufactured based on the Structural Methods stipulated by Ministry of Land, Infrastructure and Transport. Hence, a newly developed johkasou system has to obtain a certification from the administration in order to bring it into commercial use. A manual on operation and maintenance of a newly developed johkasou system should be verified and improved experimentally. Recently, newly certified johkasou systems that are more compact are increasing, and the treatment technology of johkasou system has developed dramatically.

Table 2 shows some newly developed johkasou systems, which have received certification from the Ministry of Land, Infrastructure and Transport [2]. In small-scale johkasou systems, medium of different shapes are used where microorganisms adhere and the aerobic treatment process is applied to. When the microorganisms adhere densely into the specific shaped bio-media, operation under high load is possible. Johkasou systems with this kind of biofilter have an advantage of compactness because the sedimentation tank is not needed.

On the other hand, medium to large scale johkasou systems have been certified as a new treatment technology that uses media of different shapes and uses same treatment process as activated sludge processing which are used in small-scale johkasou systems. In addition, attention is given for the johkasou systems using the membrane separation activated sludge process, which combined an activated sludge process and membrane separation technology. The process consists of a separation membrane unit, which is immersed directly into the aeration tank of an activated sludge process, and separates collects the treated water from the mixed liquor. It is important to find the suitable operating conditions for stabilizing operation and good effluent quality. It is also essential to find the suitable operating condition to reduce the problem like membrane clogging [5].

Table 2 Example of Johkasou Systems using new technology

Scale	*Process*	**Treatment water quality**	**Technical point**
Small	Flow equalization type anaerobic filter contact aeration with nitrified mixed liquor recycle process	BOD: 20[mg/L] T-N: 15 [mg/L]	Flow equalization function, Denitrification process with nitrified mixed liquor recycle
	Flow equalization type anaerobic filter fluidized bed biofilm filtration with nitrified mixed liquor recycle process	BOD: 20[mg/L] T-N: 20[mg/L]	Flow equalization function, Denitrification process with nitrified mixed liquor recycle , Fluidized bed+Biofilm filtration
	Flow equalization type anaerobic filter biofilm filtration with nitrified mixed liquor recycle process	BOD: 10[mg/L] T-N: 10[mg/L]	Flow equalization function, Denitrification process with nitrified mixed liquor recycle, Biofilm filtration
Medium Large	Batch type intermittent aeration activated sludge process	BOD: 20[mg/L] T-N: 15[mg/L]	Batch system, Intermittent aeration denitrification
	Nitrification and denitrification by recycling nitrified mixed liquor in membrane separation activated sludge process with flocculation	BOD: 5[mg/L] T-N: 15[mg/L] T-P: 0.5[mg/L]	Denitrification process with nitrified mixed liquor recycle, Phosphorous removal by flocculation

CONCLUSIONS

BOD, nitrogen and phosphorous removal technology in johkasou systems has been explained. There are various ways of wastewater treatment technology but the johkasou systems applied is a few. Development of new johkasou systems is now very active. Even we can develop johkasou systems with further advanced treatment performance by the technology though new research and development, we have to keep in mind about the easy maintenance of the johkasou systems, which has already demonstrated. Moreover, it is difficult to develop new johkasou systems but we have to continue our further challenges for excellent johkasou systems.

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Operation, Maintenance and Examination of Johkasou System

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INTRODUCTION

The domestic wastewater treatment system can be divided into three types as follows:

① Small scale systems for only treating flush toilet wastewater,
② Small to medium scale systems for treating miscellaneous domestic wastewater,
③ Large scale systems for treating miscellaneous of domestic wastewater.

①and②systems are called johkasou system mainly installed/constructed by individuals or municipalities. ③system is called sewerage system mainly constructed by municipalities of cities, towns and villages.

There are 1,638 sewerage treatment facilities in 2000 FY. These facilities are maintained by public sectors. On the other hand, nine million johkasou systems have been installed and maintained mainly by private sectors. Sewerage treatment facilities are maintained mainly by resident maintenance engineers, but johkasou systems are periodically maintained once a week, a month, several months and so on.

Since processes of wastewater treatment are composed of physical, chemical and biological treatment and there are public health problems, special knowledge is needed for operators. For that reason, qualification systems are being laid down for training technicians.

Johkasou systems are small scale and decentralized systems and the treated water is discharged into rivers, so johkasou systems are highly favorable to the reservation and improvement of water environment. To maintain effluent qualities, johkasou systems should be properly maintained and managed. In this paper, the maintenance and management (maintenance, desludging and inspection) of johkasou systems in Japan is introduced.

OBLIGATION OF JOHKASOU MANAGER AND LAW SYSTEM

In the case of sewerage systems, it is essential to keep each unit of equipment of wastewater treatment plants run in good condition in the daily operation and maintenance.

In the case of johkasou systems, they are periodically maintained due to its small scale, and designed for lightening the burden imposed on johkasou users. However, it is necessary to consider the fluctuation in the period of maintenance from a regular state to an irregular state and the change of temperatures throughout the year to operate.

Also, it is necessary to adjust the operation of johkasou systems according to the use purpose of buildings (houses, shops, schools and so on) where johkasou systems are installed, and the change of properties of wastewater at different time (day, week, month and so on).

To get the designed performance, johkasou systems must be used correctly. As a statutory obligation, the johkasou manager, as the responsible person among johkasou users, must periodically maintain the johkasou system and desludge the accumulated sludge out the johkasou system.

Since not every johkasou manager has the special knowledge of maintenance and desludging, the businesses of maintenance and desludging are mainly entrusted to johkasou maintenance vendors and johkasou desludging vendors. As another statutory obligations, the johkasou manager must receive an annual water quality examination to evaluate whether the maintenance and desludging of johkasou system were correctly executed and designed performances were obtained. The water quality examination is executed by the inspection agency specified by the prefecture governor. Figure 1 summarizes the general system for maintenance, desludging and examination of johkasou systems.

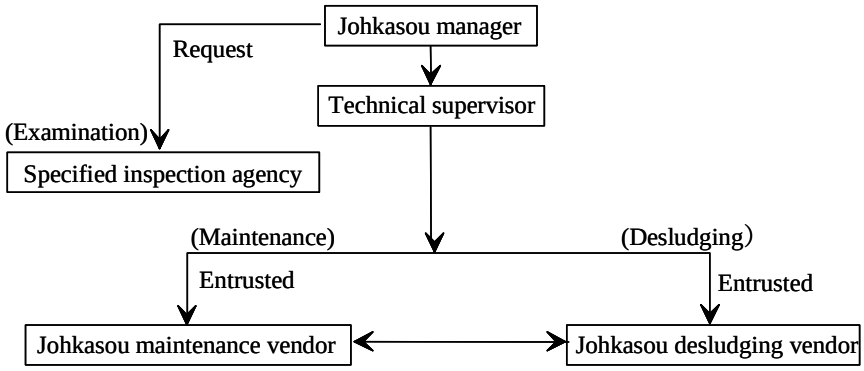

Figure 1 Organization for Maintenance, Desludging and Examination

All items of maintenance, desludging and examination that must be carried out are regulated by the Johkasou Law and related rules. However, johkasou systems are always remarkably developing and new treatment technologies are continuously occurring with that development, so it is also needed to strive continuously to have management guidelines and the new knowledge of proper management spread widely and thoroughly.

MAINTENANCE

Maintenance operations are necessary to adjust the johkasou system or repair it as required. More specifically, these operations include monitoring the operational conditions of each unit equipment of the facility and the auxiliary equipment, and the water quality of the final effluent, in order to discover faults or defects earlier and take corrective action.

At the beginning of maintenance, it is necessary to check up the way of water flow in inflow and outflow pipes, the installation condition of each equipment and the operation condition, and confirm whether wastewater is quickly treated or not.

The basic viewpoints about the common maintenance are arranged as follows:

(1) To prepare tools and machines according to treatment processes and facilities of johkasou system for making sure that maintenance can be reliably carried out.
(2) To make out and preserve lists that can record maintenance contents of installed johkasou system and be useful for understanding the variation and change of performance of johkasou system.
(3) After arriving at the field, to immediately examine the odor and the noise around the johkasou system, the sealing condition of service exit and manhole, and the condition of subsidence and upsurge of ground.
(4) To check up the way of water flow from inflow of wastewater and outflow of treated water.
(5) To examine the performance of johkasou system and the operation condition of each unit equipment and maintain the johkasou system corresponding with the examination result.
(6) To measure the water quality for evaluating the performance of each unit equipment and confirming whether the performance is normal or not, and to find the cause of change of water quality and take measures to keep the performance in a good condition if the change of water quality is confirmed.
(7) To periodically measure the effluent quality and check up whether the effluent quality meets water quality regulations at the outflow point of effluent, and examine whether the performance is in a good condition.
(8) To examine the accumulation condition of sludge and judge the time when the sludge is needed to be transported or carried out.
(9) To examine operation conditions of mechanical apparatus and electric equipment, adjust these apparatus and electric equipment, and make them operate normally, periodically do that maintenance.

The following contents showed items of maintenance for a johkasou system with anaerobic filter-contact aeration process that is one kind of widely used gappei-shori johkasou system for household:

(1) For the anaerobic filter tank, to measure the transparency and pH of the effluent and check up the

condition of sludge accumulation, and if the amount of accumulated sludge is considered to be near the storage capacity limit, to contact with the johkasou manager or the johkasou desludging vendor requested by the johkasou manager,

(2) For the contact aeration tank, to measure the water temperature, transparency, pH, and dissolved oxygen in the tank, then check up the amount and color of the bio-mass attached to the contact media, and if the bio-mass is found to have grown thick, to forcibly separate them by back-washing and transfer the separated sludge to the anaerobic filter tank.

(3) For the sedimentation tank, to measure the transparency and pH of its effluent and check the condition of sludge accumulation, and if scum or deposited sludge is found, to transfer it to the anaerobic filter tank.

(4) For the disinfection tank, to check up the residual amount of chlorine disinfectant in the disinfectant column and measure the residual chlorine in the effluent, and if necessary, to replenish the column with chlorine disinfectant.

(5) For the blower, to check up and clean the air-filter and repair each component according to its maintenance results.

Technique innovation of johkasou system has remarkably advanced. For example, the media floating process which makes specific area increase and a lot of bio-mass can be attached, the biofilm process (such as biological filter process), the MF membrane separation activated sludge process, and so on were developed. These processes have the capacity of nitrogen removal by using nitrified water recirculation technique or intermittent aeration technique. For operating these processes properly, it is needed to understand internal structures and facility sufficiently. Specially, as to the flow rate adjustment device, the adjustment of automatic back-washing device and membrane separation operation, it is necessary to add seed sludge properly, adjust the time of intermittent aeration, and wash membrane periodically.

Only qualified johkasou operators can maintain the johkasou system. By the end of January 2003, there are about 56,000 qualified johkasou operators. This qualification can be acquired by passing the designated national examination or by completing the lecture course approved by Minister of the Environment.

The national examination and lecture subjects include:

- Introduction to johkasou system
- Administrative management of johkasou system
- Structure and function of johkasou system
- Introduction to johkasou construction works
- Inspection, adjustment, and repair of johkasou system
- Management of water quality
- Introduction to desludging of johkasou system

It is necessary to make the education environment satisfactory for the self-knowledge and development of qualified johkasou operators, because new techniques and software for johkasou systems will be developed and new goals for improving effluent quality will be requested even after operators get the qualification.

DESLUDGING

Desludging involves withdrawing the generated sludge and scum from the johkasou system and conditioning sludge in the tank. The primary purpose of desludging is to withdraw sludge from the inside of facility before accumulated sludge flows out with the effluent.

The content and the minimum frequency of desludging like maintenance are stipulated by Ministry of the Environment.

For example, in the case of a household use of gappei-shori johkasou system with the anaerobic filter-contact aeration process, the desludging should be done at least once a year according to the regulation, and the content of desludging is as follows:

(1) To use a vacuum truck capable of carrying 2 to 4 metric tons sludge.

(2) For the 1st room of anaerobic filter tank, to withdraw all scum and deposited sludge, wash the pressing cover of the filter media with tap water, then withdraw all the water from the bottom of the tank.

(3) For the 2nd room of anaerobic filter tank, to contact aeration tank, sedimentation tank, and

disinfection tank, the necessary amount of water to be withdrawn is variable, depending on the condition of sludge accumulation in each unit equipment.

(4) After withdrawing sludge, to fill the tank with tap water to the designated level.

(5) To carry the withdrawn sludge to the sludge treatment facilities (for example, night soil treatment facilities) for sanitary treatment.

The ratios of johkasou sludge actually treated and disposed by different ways in 2000 FY are as follows: 89.7% by night soil treatment facilities, 4.8% by dumping into the sea, 5.0% by dumping into sewerage systems, 0.2% by others. The amount of sludge dumped into the sea is gradually declining, but it is decided that dumping sludge into sea will be wholly abrogated from 2007 and all sludge will be treated on land, corresponding to London Treaty that prohibited dumping sludge into the sea.

It is prospected that expectations for the small-scale johkasou systems will be enlarged and installations of the johkasou systems will be increased due to the spread of large scale of sewerage systems and the tight local financial conditions. The generated amount of sludge from johkasou systems will be increased with the spread of johkasou system, so it is hoped to expand and improve the facilities used for treating or recycling sludge.

It is noticed that some johkasou desludging vendors have started in early stages to run the business of sludge recycling, and introduce sludge concentration trucks and sludge dehydration trucks for improving the efficiency of sludge collection and transportation. The sludge treatment by private sectors is highly being expected.

To upgrade the vocational skills of johkasou desludging vendors, various lecture courses are offered, such as “Training course for qualification of johkasou desludging technicians” and “Training course for johkasou desludging workers”. By the end of January 2003, there are about 13,000 johkasou desludging technicians and about 9,600 desludging workers who have passed “Training course for johkasou desludging workers” in Japan.

LEGAL EXAMINAITON

According to the Johkasou Law, johkasou managers must grasp the installation and operation condition, treatment performance of their johkasou system objectively, and make their johkasou system to be examined on water quality by specified inspection agencies.

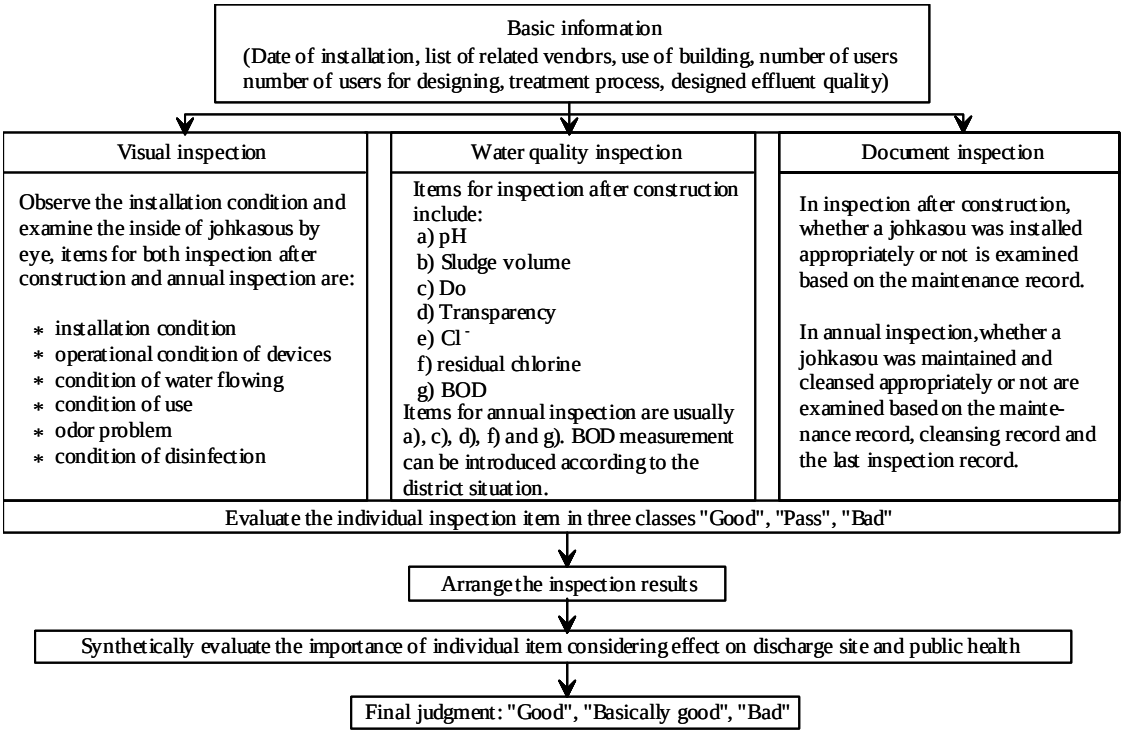

Figure 2 Inspection content and procedure of legal inspection

There are two kinds of legal inspection: examination after construction and annual examination. The items and procedure are summarized in figure 2. Periodical maintenance and desludging for johkasou systems are just like daily health control for the johkasou system, and the annual examination can be thought as a medical examination for the johkasou system. By the annual examination, whether a johkasou system is maintained in a normal condition or not is examined objectively by the third party of specified inspection agencies that work as a public service corporation. Therefore, maintenance, desludging and annual examination for the johkasou system differ each other in their objective and content, and are executed in different viewpoints. All of them are essential to keep the johkasou system in good treatment performance.

Specified inspection agencies are designated by Minister of the Environment when their service area covered more than on prefecture, or by the prefecture governor when their serve area is limited in one prefecture. By the end of April 2002, there were 67 public service corporations are designated as specified inspection agency, while there were 945 qualified inspectors in the agencies.

CONCLUSIONS

Johkasou systems that are installed separately are very effective and suitable for Japan because of the situation of land use and the condition of massed population in Japan. It is inevitable to require high level of technologies when spreading the johkasou system. Simultaneously, the plan, design and construction of johkasou system are important. Furthermore, the maintenance of johkasou systems is also important for continuously getting the designed performances of the johkasou system. The Johkasou Law has been established in order to regulate the plan, design, construction, and maintenance and so on of the johkasou system.

Johkasou managers obligate the maintenance and management of johkasou system in Japan, but most of maintenance and management businesses are entrusted to johkasou maintenance vendors since not every johkasou manager has special knowledge on maintenance and management of johkasou systems. The maintenance and management include the maintenance and desludging which are periodically executed (once a week, a month, and several months) and the examination that is executed for confirming whether maintenance and desludging are accurately executed. In any cases, it is important that each of qualified johkasou technicians responsibly executes these businesses for obtaining the designed performances of johkasou system.

In conclusion, the johkasou system is formed on the basis of the high technologies and the system composed of the training of technicians, the cooperation between the government and private enterprises, and laws concerning design, construction and maintenance of johkasou system.

Proceedings of Johkasou Session, the 3rd World Water Forum
16th March 2003, Kyoto, Japan

National Promotion Programs for Domestic Wastewater Treatment by Johkasou Systems

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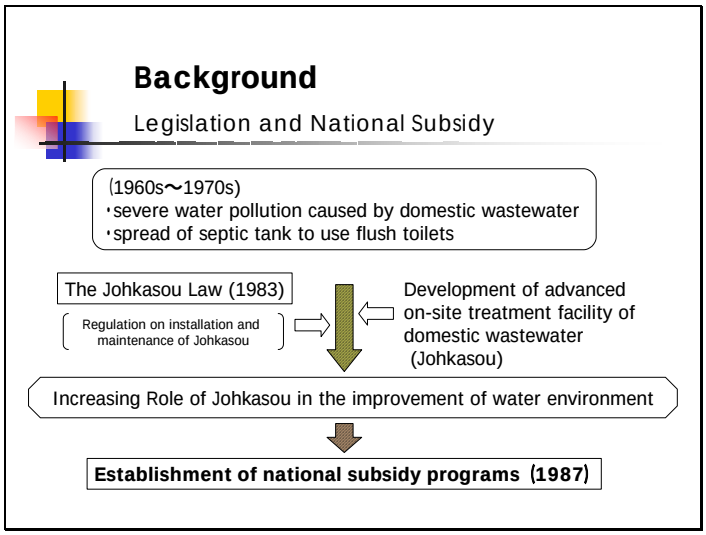
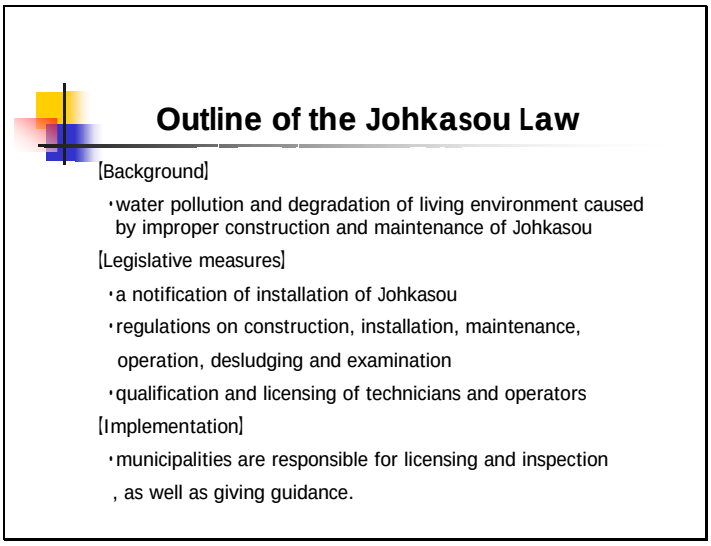


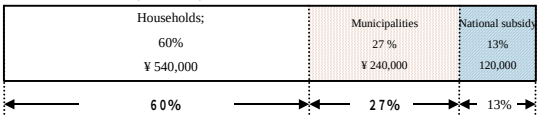


Outline of National Subsidy (1)

① For households (1987～)

The households can get the national subsidies for the 13% of total cost to install johkasous, when the municipalities have subsidy program.

【Share of households, municipalities and national government for installing a Johkasou of 5 equivalent person】

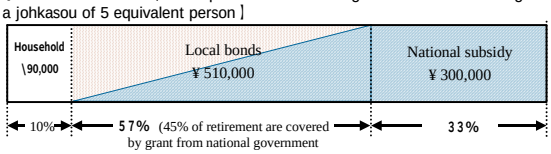


Outline of National Subsidy (2)

② For municipalities (1994～)

The municipalities can get national subsidy for the one-third of the total cost to install johkasous, bearing the responsibility of maintaining the facility.

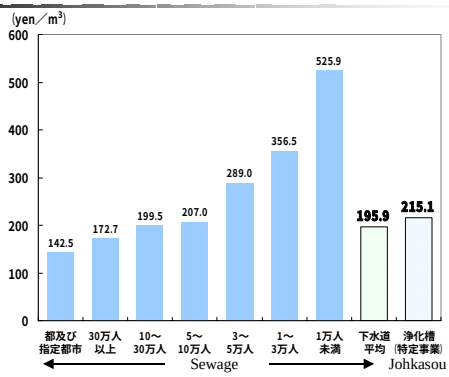
【Share of households, municipalities and national government for installing a johkasou of 5 equivalent person】



【areas】

- the source of water supply, lake, inland sea, etc.
- regions where the total cost to install johkasous is smaller than sewerage.

The Cost of wastewater treatment



Advantages and Disadvantages of Johkasou

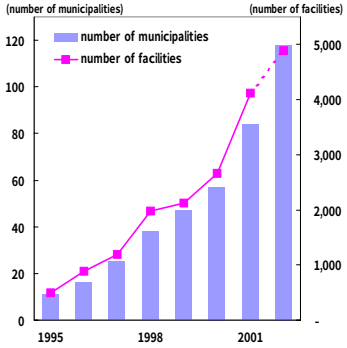
[Advantages]

- Municipalities can take the similar financial measures to provide their wastewater treatment service in johkasou systems and sewerage systems.
- The household with on-site treatment system may take care of their wastewater.
- Municipalities can promote their wastewater treatment service according to an areal installation plan.
- Johkasou costs less than sewage.

[Disadvantages]

- Some households have no room to install a johkasou.
- Some households refuse to install a johkasou.

Achievement of the National Subsidy for Municipalities



Areas

- rural area with scattered houses
- regions where sewage is not available because of financial and topographical conditions
- lakes, inland seas, etc.

Future Challenges

- To development of efficient and economic plan of wastewater treatment facilities
- To increase the role of municipalities to install Johkasou
- To introduce PFI
- To switch from septic tank to Johkasou to improve water environment
- To improve operation and maintenance of Johkasou

The Experience of Sanuki City in Promotion of Domestic Wastewater Treatment by Johkasou Systems

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INTRODUCTION

Sanuki City is a nature rich city, located east of Takamatsu City in Kagawa Prefecture, north of the Sanuki mountainous district and south of the Seto Inland Sea. It was amalgamated from Tsuda Town, OkawaTown, Shito Town, Sangawa Town and Nagao Town in western Okawa County as the 6th city in Kagawa Prefecture. It has an area of 15,881km^2, about 20,000 households and a population of 57,000 people.

Sanuki City, amalgamated from 5 towns, has various domestic wastewater treatment systems depending upon the system of the original town. There is only one independent treatment system formed by the Gappei-syori Johkasou Installation Promotion Project in Sangawa Town. In the other four towns, there is an aggregation of treatments formed mainly by a sewerage system and a collective independent treatment system.

The operation and maintenance of johkasou systems is carried out by the administrative maintenance scheme in Sangawa Town. This system has been concluded as a joint project in the amalgamation agreement book.

Sangawa Town is a small town located in the center part south of Sanuki City with an area 23.10km^2 and a population of 6,000 people. As a "Hometown Environmental Improvement Project", Johkasou Installation Promotion Project in Sangawa Town progressed steadily through the guidance of the country and the prefecture in the 1987 fiscal year. By the end of 2001 FY, the number of installed johkasou systems reached 1,147 units, the population served was about 4,900 residents for a rate of about 73% of the 1,580 generally owned houses (Document A: Establishment of Johkasou Systems in Sangawa Town).

FEATURES OF THE PROMOTION PROJECT

Sangawa Town has advocated the "Establishment of Agricultural Towns". The water source for agriculture was taken from rivers and irrigation ponds, but about 90% of the miscellaneous domestic wastewater was discharged into the agricultural water aqueduct, and about 10% to rivers and irrigation ponds. Therefore, the deterioration of the environment and the preservation of the quality of agricultural water were an administrative theme. With this background, the johkasou installation promotion project was undertaken in Sangawa Town to meet the desire of regaining the original beautiful appearance of the town, living in the abundant spectacle of nature with beautiful water and fertile soil, and protecting the living standards of its residents. Since living conditions are surely improved the installation of johkasou systems in 1/3 of the homes, a goal was promoted to install 1,000 more units (in about 2/3 of homes) in Sangawa Town at the beginning.

In addition, Kagawa Prefecture is in the Seto Inland Sea type climate zone where precipitation is less than the average level of the country as a whole. Its average annual precipitation is 1,200 mm, greatly below the 1,800 mm of the national average precipitation. As the 200 ponds in Sangawa Town show, past efforts to secure a reliable water supply have been repeatedly made.

Presently about 20% of the agricultural water is taken from the Yoshino River of Tokushima Prefecture, part of the Kagawa service water.

Similarly, the drinking water is got from the underflow of a second-class river and seven shallow wells at four different water sources since the 1978 fiscal year. Every winter, Sangawa Town suffers from water shortages when the water level of the well decreases, and water is supplied to each home by the assistance of water supplied from the neighbouring town. Therefore, the residents are intent to find a secure source of water.

Under such circumstances, 675 johkasou systems have been set up and 605 other units have been maintained at the end of the 1992 fiscal year. As a result, fireflies and corbicula that were thought to have died out in the area have returned to the agricultural water aqueduct and the river. The effect of promoting johkasou systems exceeds the forecast for water pollution control and securing water sources in the public

water bodies.

The johkasou installation promotion project of Sangawa Town is a domestic wastewater treatment measure project designated by all areas as a model project area. A big feature of the project is that the administration participates in maintenance management. This system should also be seen as a prototype for domestic wastewater treatment projects for specified areas.

The "Hometown Environmental Promotion Project Conference" organized from the administration, the town assembly and the inhabitants, administers the project. This conference recognizes the johkasou installation as a public works project, aligns the johkasou systems to public utilities installed in the individual water treatment facility for the public water body. At receiving the delivery application of the trust of installation and subsidy from the residents, the conference was entrusted the maintenance as an obligation.

Controlling the water treatment facilities properly is by all means necessary. The johkasou installation project would be ineffective if not managed properly.

The merit of maintenance through this conference, the Johkasou Installation Promotion Project, is that the installed johkasou systems can be maintained and managed perfectly. The conference can guide the johkasou maintenance/desludging vendors, which provide maintenance for the johkasou systems, to stabilize the treatment performance by supplying the disinfectants, desludging the sludge at suitable time, and quickly making repairs. Because the cost for maintenance is collected at every month in a fixed amount, it doesn't become a burden on housekeeping expenses as well.

From the position of the johkasou vendors, they make contracts with the conference not with individual householders; they do not need to worry about the collection of fees and maintaining separate contracts with each individual household. This helps them create a yearly business plan easily.

This system was constructed under the condition when not even one johkasou had been installed, and started with an independent standard that was not restricted by established concepts. The understanding and cooperation could be got from the residents, the water supply association and housewives especially. Furthermore, cooperation is came from the johkasou vendors themselves (same as the johkasou desludging vendors) and the johkasou contractors (in the case of Sangawa Town, the johkasou manufacturer). These are the reasons that this maintenance system is functioning smoothly at present.

Excluding the administrative cost of the conference, the management of the johkasou systems can be done with just a trust charge from the residents (Document B: Maintenance Revenue), there is no town fiscal burden for maintenance in the next fiscal year.

Another feature is expanding the range of the subsidy in the installation/construction of the johkasou systems. At the project start in 1987 FY, more than 470 tandoku-shori johkasou systems had already been installed. It must be understood that the main factor causing water pollution was the pollution loads from the kitchens, the bathes, and washing machines, rather than human wastes. Therefore installing gappei-shori johkasou systems, rather than tandoku-shori johkasou systems, was encouraged by offering additional assistance above the usual subsidy. In addition, although in the normal cases only the installation of the main unit of a johkasou system is subsidized, in Sangawa Town the whole system from soil water basin to inflow pipe to the main unit to the outflow is subsidized.

Another feature is that the recycling of wastewater that can be used as a resource has been achieved. According to the history of Sangawa Town, drought occurs frequently, every four-five years. This drought often results in the damage of agricultural products up to 50%. Recently in 1994, damage to farm products especially rice has occurred because of an abnormal water shortage in the every part of Kagawa Prefecture. However, in Sangawa Town, excluding the mountainous areas, the damage hardly occurred due to the water recycled from the johkasou systems. Although it depends on the topographical conditions, miscellaneous domestic wastewater purified by johkasou systems is reused as agricultural water, and then the agricultural runoff percolates through the river and the soil to replenish the underground water source. The result is that the circulation of the water for the residents using underground water as an aqueduct water source can be assured.

FURTHER CHALLENGES

As a future problem, johkasou systems cannot be installed/constructed in crowded residential areas because there is not enough room. Even if a site is reserved, it may be too narrow to install a johkasou there. The problem can be solved by installing a johkasou in the road site, where the road traffic cannot be disturbed by amending the Road Traffic Act, encouraging the manufacturer to create more compact products or

introducing small scale centralized treatment systems.

In addition, there is a problem of fairness to the residents for the burden of maintaining the johkasou systems. At present, the cost for maintenance has been collected according to the numbers of users for designing (NUD), which is calculated not by the actual number in the household but by the total floor area under the building. Since rural houses are large, johkasou systems installed before the flexible regulation are almost always johkasou systems of 10 NUD. Entering an aged society with fewer children, many families are usually two-person family. For this reason, it is necessary to consider a more equitable method for shouldering the burden of the cost for maintenance based on the pollution-loading amount to the public water bodies. The johkasou sludge is decreased by dehydration, so that the burden is lightened collectively by reducing the cost.

CONCLUSIONS

Since long ago, the sludge from johkasou systems was simply dumped into the open sea off of Wakayama Prefecture. Presently, part of the sludge is disposed of by incineration at an inland processing facility. Since the sludge from johkasou systems does not contain harmful matters, unlike the sludge of the centralized treatment facilities, it can be used to make products at the processing institution serviced. In today's recycling society, the recycling type wastewater treatment system of the johkasou system is required.

If the treatment facility for the water environmental preservation is constructed intensively in one place, it will become a problem. By installing small-scale facilities at every scattered generation source, wastewater treatment will be carried out dispersedly. This is advantageous to water-resources preservation and is also connected to the promotion of self-purification of the whole drainage basin. We are convinced that the living environment is improved and that the effluent of the johkasou systems can be utilized as a water resource effectively through proper maintenance.

Lastly, we should re-recognize the fact that it is a time when the match of environmental problem one by one is required. During this kind of age, we should endeavor to the environmental preservation of the home by selecting the domestic wastewater treatment project suited to the actual condition of the region.

Document A

Establishment of johkasou systems (1987～2001)

・ Number of johkasou systems installed

Number of users	Number of units	Population served (people)	Percentage to total units(%)
5	236	734	20.6
6	210	808	18.3
7	333	1,620	29.0
8	126	603	11.0
9	5	30	0.4
10	234	1,144	20.4
12	1	0	0.1
18	1	0	0.1
25	1	4	0.1
Total	1,147	4,943	100.0

・ Total operational costs

Classification	Total (1000Yen)	Percentage to total costs(%)
National subsidy	198,617	16.7
Prefecture subsidy	136,563	11.4
Town subsidy	545,590	45.8
(Subsidy) Total	880,770	73.9
Individual share in the cost	311,430	26.1
Total operational costs	1,192,200	100.0

Document B

Maintenance revenue (1988～2001)　　Number of units maintained　10,212 Units

・ Income　　Unit：Yen

Total income	Reference
367,197,100	Costs of maintenance entrusted (per monthly) Plant for 5 people　2,800Yen ・ Plant for 6 people　3,000Yen Plant for 7～10 people　3,300Yen

・ Expenses　　Unit：Yen

Total expenses	Items				Reference
	Maintenance costs	Sludge withdrawal costs	Repair costs	Other	
357,296,281	102,159,759	203,158,425	38,797,325	13,180,772	

・ The balance of income and expenses

・ Income － expenses ＝ The balance carried forward

367,197,100Yen － 357,296,281Yen ＝ 9,900,819Yen

Environmental Sustainability, Ecological Sanitation and the Gappei Johkasou

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INTRODUCTION

The purpose of this paper is to reexamine the 'gappei johkasou' (combined johkasou) concept in the light of current ecological thinking. The gappei johkasou unfortunately has some serious flaws. But it also has some favourable features and I believe that if we bring together the 'don't mix' approach of ecological sanitation and the advanced treatment of the gappei johkasou we have a winner - a system that can be applied not only in Japan but also in many other countries. The potential market is enormous: The UN has defined the global sanitation crisis as the 2.4 billion people in the world today without basic sanitation. This is probably an underestimation (Simpson-Hébert et al 2003).

After defining the problem, I shall describe and comment on the 'gappei johkasou' and on 'ecological sanitation' and finally discuss how we can combine the best features of both into what we may call the 'ecological johkasou'.

THE PROBLEM

The basic problem is how to handle the excreta and wastewater generated in human settlements.

SLIDE 2: text below

A household of 4 persons produces about 200 litres of faeces and 2,000 litres of urine per year. To flush it away the household would use at least 60,000 litres of water. In most cases another 200,000 litres of greywater from kitchen, bath and laundry is added.

Human societies have developed various ways of coping with this problem.

One way of doing it is to use the nearest river as a toilet.

SLIDE 3: open defecation

A more refined method is to drop the human excreta in a WC connected to a public sewer.

SLIDE 4: WC

We press a button and the faeces and urine disappear down a pipe, transported by the flushing water. Convenient and hygienic! But where does it go? What happens at the other end of the pipe?

SLIDE 5: discharge of untreated sewage

At the end of the pipe there might be a treatment plant, but in most cases, globally, sewage is discharged directly into a river, lake or the sea (Matsui 2002). – Strangely enough, this primitive disposal system is regarded by most people as the ideal solution in spite of the fact that it creates more problems than it solves:

SLIDE 6: text below

- the investment costs as well as operation and maintenance costs are high (in Japan JPY 1.5-2.0 million per capita, 70% of which is for the pipe network);
- it requires large amounts of water for flushing and transport;
- leaking sewers pollute groundwater;
- untreated discharge pollutes surface water;
- even after treatment in a conventional treatment plant we are still left with bio-active substances such as hormones and antibiotics;
- the plant nutrients (nitrogen, phosphorous and potassium) in the human excreta are not returned to the soil;
- the more effective end-of-pipe treatment we introduce, the more sludge we must get rid of.

THE GAPPEI JOHKASOU

The non-Japanese participants may not be familiar with the 'johkasou'. The word littertally means 'tank for purifying'. It is a kind of high-tec septic tank for sedimentation, aerobic treatment, disinfection and separation of liquids and solids.

SLIDE 6: the gappei-shori johkasou

After disinfection by caciumhypochlorite the liquids are discharged into the nearest gutter or ditch.

SLIDE 7: liquid discharge

According to the Johkasou Law of 1983 the BOD of the discharge must not exceed 20 milligramme per litre.

The solids (sludge) are collected by a vacuum truck, usually once a year, and brought to a nightsoil treatment plant.

SLIDE 8: johkasou system - diagram

There are more than 1,000 nightsoil treatment plants in Japan, serving about 35 million people (Matsui 2002). Many of these plants use sophisticated technologies for treating the nightsoil: the activated sludge method, biological denitrification, phosphorus removal by chemicals, separation of liquids and solids (sometimes by high-polymer membranes), and colour removal through ozone processing. The liquid fraction is discharged, the solids are usually landfilled.

Some of the problems with public sewage systems mentioned earlier we can also find with the gappei johkasou:

SLIDE 9: text below

- the cost is less but is still much too high for most developing countries;
- water consumption is high as standard WCs are used;
- the partly treated discharge pollutes surface water;
- the plant nutrients in human excreta are not returned to the soil;
- the problem of sludge disposal remains.

What can we do to reduce these problems? – Can we adopt some of the features of 'ecological sanitation'?

ECOLOGICAL SANITATION

By mixing faeces, urine and water, the conventional public sewage system makes the original problem much larger. A rather small amount of excreta is allowed to pollute a huge amount of flush water and an even larger amount of greywater.

Ecological sanitation is based on the realization that to solve the problem we need to take a whole-systems approach to the metabolism of human settlements (Esrey et al 1998). If we do that it becomes quite clear that the nutrients in the plant–food–excreta cycle must be returned to the soil.

SLIDE 10: closed loop diagram

In its practical application ecological sanitation makes use of 3 basic concepts: diversion, dehydration and recycling.

Diversion means that we keep faeces and urine apart.

SLIDE 11: squatting pan and seat riser with urine diversion

This is facilitated by the fact that faeces and urine leave the human body from different openings and take off in different directions. Faeces are allowed to drop straight down into a processing chamber, urine is collected in the front part of the specially designed squatting pan or toilet seat-riser.

What do we gain by that? – First of all we reduce the amount of dangerous material that we have to handle. Urine is virtually sterile when leaving the human body, it does not directly spread any infectious diseases, is easy to handle and contains most of the nitrogen-phosphorus-potassium plant nutrients. Urine can be used directly as a fertilizer or the nutrient salts can be extracted.

SAMPLE displayed

As human faeces may contain pathogenic organisms they must be confined in a processing chamber during their most dangerous period.

SLIDE 12: processing chambers, outside

During confinement, normally for 6-8 months, the faeces are dehydrated to a moisture content of <30%.

SLIDE 13: processing chamber, inside

After that they may be moved to an on-site or neighbourhood composting station ('eco station') for secondary processing, for example by high-temperature composting.

SLIDE 14: neighbourhood composting station

Finally the solids are recycled as fertilizer and soil conditioner.

SLIDE 15: greenhouse

A few international examples:

SLIDE 16: dry toilet in Guangxi

This is an example from a fairly large-scale application of ecological sanitation in Guangxi Region in southern China. Over the past four years 30,000 households have been provided with urine-diverting dry toilets of this type. This achievement is the result of an international research and development programme

on ecological sanitation funded by Sida, the Swedish International Development Cooperation Agency (the Swedish equivalent of JICA).

SLIDE 17: dry toilet in Mexico

In Mexico ecological sanitation toilets are promoted by a number of NGOs and environment conscious citizens. The example is from a house in an urban area near Mexico City. This is also a urine-diverting dry toilet. Under the bathroom there are two processing chambers for faeces.

SLIDE 18: dry toilet in Mexico – output

The pictures show what the output from the processing chambers looks like. It is greyish in colour from the ash and lime that is used to sanitize the faecal material by increasing the pH (to above 9.5).

In Sweden most households are connected to public sewers but there are also smaller projects testing ecological sanitation.

SLIDE 19: Kalmar University – urine-diverting toilet

The picture shows a toilet at the Science faculty building of Kalmar University in the south of Sweden. Urine is diverted, faeces are flushed with a small amount of water to processing chambers in the basement of the building.

SLIDE 20: Kalmar University – processing chambers

The flush water and the solids are separated in a simple device placed on top of each chamber. The liquid is sterilized with ultraviolet radiation, the solids are composted in the processing chamber.

THE 'ECOLOGICAL JOHKASOU'

If we combine the whole-systems approach of ecological sanitation and some of the advanced technologies of the gappei johkasou and of greywater treatment we should be able to develop an entirely new system for the management of human excreta and greywater.

SLIDE 21: text below

I have tentatively called this new system the 'ecological johkasou'.

What would characterize an ecological johkasou system? – The 'whole-systems approach' means that we consider the johkasou as part of a larger ecological system with components like food production, water supply, municipal economy, and soil fertility. As the earth is a closed system nothing permanently disappears. What we flush away in a WC will sooner or later turn up as a pollutant somewhere else. The whole-systems approach must therefore be based on recycling rather than dumping and diluting.

The starting point in the design of such a system should be source control: Don't mix: collect urine, faeces and greywater separately and process them separately (Winblad 1998).

SLIDE 22: 3 streams – yellow, black, and grey

The yellow stream goes to an on-site storage tank from where it is periodically removed by vacuum truck for direct use as fertilizer or as raw material for fertilizer.

SLIDE 23: spreading urine on farmland

One possibility is to produce MgNH3PO4 (MAP) powder from the urine (Miyagoshi 2003). The method has just been developed at Kyoto University.

The black stream goes to an on-site processing chamber.

SLIDE 24: processing chamber /Järna/

from where it is removed by vacuum truck and taken to a fertilizer factory (could be an upgraded night soil treatment plant) where it can be processed with other organic waste.

The grey stream is treated on site or in the neighbourhood through sedimentation and biological filters (Matsui 2003). An alternative is to treat the greywater in constructed wetlands or in evapo-transpiration beds (Esrey et al 1998).

SLIDE 25: evapo-transpiration bed in Kerala, India

Another important point is to use a minimum of water. You have already seen examples of ecological sanitation that works well without any water at all. You have also seen examples where a very small amount is used to transport solids the short distance to an on-site tank.

SLIDE 26: 2 examples of ecological sanitation that work well

A third possibility is to use a vacuum system for the black stream (Matsui et al 2001).

The technologies we need for collecting, transporting and treating these three streams exist - in Japan and in many other countries. The task is basically to select the best and adapt them to the whole-systems approach.

Most of the world has been tricked into believing that the modern way of managing human excreta and greywater is to flush them away, discharge the effluent into the sea, and bury the sludge. This is basically 19th century technology, sometimes tarted up with 20th century gadgetry.

SLIDE 27: old-new WC

This is not only the most expensive way of doing it – it also wastes water and plant nutrients (particularly

phosphorus that is a limited resource). The conventional public sewer system is expensive even for rich communities. In the European Community, only 79 of 542 cities have advanced sewage treatment and 44% have no treatment or incomplete primary or secondary treatment. In Eastern Europe, despite widespread urban sewerage, there is nearly a total lack of even primary treatment of wastewater discharges, resulting in widespread pollution and eutrophication of receiving waters. (EU 2001)

The cost in environmental pollution and in human lives due to death from diarrhoeal diseases will be heavy in urban areas of developed and developing countries if they continue to discharge under-treated wastewater into the open environment. We will see the build-up of toxic substances in groundwater, rivers and lakes and the intensification of endocrine disruptors ('environmental hormones') that impact upon plant, animal and human reproduction and immune systems. The entire planet is in a sanitation crisis, and the time has come to try radically new solutions. These solutions must be based on ecological principles – solutions where all nutrients are recycled and where pathogens are destroyed through natural and cost-effective processes. I am convinced that the ecological johkasou could be one of these solutions.

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