# Chapter 9
# Management of On-Site Household Wastewater Treatment Systems (*Johkasou*) in Japan

**Yasushi Ishiguro and Fusheng Li**

**Abstract** *Johkasou* is an on-site wastewater treatment system that was developed and is widely used in Japan. In this chapter, the actual usage of *Johkasou* in Japan, as well as their design, maintenance, and management are introduced. In addition, the knowledge gained from our research on their management and the operating conditions required to improve the quality of treated water is discussed.

**Keywords** *Johkasou* · On-site wastewater treatment · Household wastewater · Management

## 9.1 Introduction

When wastewater is discharged into the aquatic environment, it is mixed with water, and the pollutants are purified over time by the self-cleaning processes. However, if the amount of pollutants exceeds the self-cleaning ability of the rivers and other water bodies, the pollutants will flow into the water, and water pollution will progress. The main domestic wastewater treatment systems in Japan are sewage systems, rural sewage systems, community plants, and *Johkasou*. Among these, the centralized wastewater treatment system collects water from many remote buildings through pipes and treats all the water at a remote site. These include different types of sewage systems and rural sewage systems. On the other hand, when the wastewater is treated on the same premises as the building, it is called "onsite treatment system", and *Johkasou* is a typical example. These include small-scale *Johkasou* installed in individual homes and medium- and large-scale *Johkasou* that treat wastewater from housing complexes and public facilities such as schools, city halls, stores, and hospitals.

*Johkasou* is an on-site wastewater treatment system developed in Japan. *Johkasou* was mainly built to process wastewater generated in households that are

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F. Li et al. (eds.), *River Basin Environment: Evaluation, Management and Conservation*, https://doi.org/10.1007/978-981-19-4070-5_9

not yet connected to public sewage systems. *Johkasou,* together with the sewage system, which collects and treats wastewater from larger areas, plays an important role in maintaining a clean and comfortable living environment and preserving the natural environment. In addition, treated water from *Johkasou* is discharged into natural water bodies such as rivers and lakes in a dispersed manner through ditches and waterways, thus greatly affecting the surrounding river basin and contributing to the pollution in rivers and lakes.

Since *Johkasou* are installed in individual houses, the amount of wastewater inflow and the concentration of the pollutants varies greatly throughout the day. However, the performance of *Johkasou* in treating the wastewater is generally good. *Joukasou* performance varies depending on their type, the conditions of their usage, and their state of maintenance and inspection, which affects the treated water quality.

In this chapter, the design, maintenance, and management of *Johkasou*, their actual conditions of use in Japan are introduced. In addition, the knowledge gained from our research on the management and operating conditions of *Johkasou* to improve the quality of treated water is discussed.

## 9.2 Actual Usage of *Johkasou* in Japan

### *9.2.1 Current Status of Wastewater Treatment and Usage of* Johkasou *in Japan*

There are two main types of wastewater treatment facilities in Japan: "centralized treatment systems" and "on-site treatment systems." These two systems are used appropriately in different situations, sharing roles and responsibilities, and taking advantage of the local conditions and their respective features.

"Centralized treatment systems" transport wastewater from households and businesses in large areas through a pipeline to a wastewater treatment plant. "Centralized treatment systems" include "sewage systems" (under the jurisdiction of the Ministry of Land, Infrastructure, Transport and Tourism, Japan), which primarily eliminate and treat wastewater in urban areas, "rural sewage systems" (under the jurisdiction of the Ministry of Agriculture, Forestry and Fisheries, Japan), which treat wastewater in agricultural promotion areas, and "community plants" (under the jurisdiction of the Ministry of the Environment, Japan), which independently treat wastewater in residential complexes unconnected to public sewage systems.

On the other hand, the main type of "on-site treatment system" is the "*Johkasou*" (under the jurisdiction of the Ministry of the Environment). In areas where centralized treatment is inefficient or has yet to arrive, *Johkasou* can be installed by individuals. There are two types of *Johkasou*: *tandoku-syori Johkasou*, which treats only wastewater from toilets, and *gappei-syori Joukasou*, which treats wastewater from toilets and miscellaneous wastewater, called "gray water" such as that from kitchens, laundry rooms, and bathrooms. In *tandoku-syori Johkasou*, only

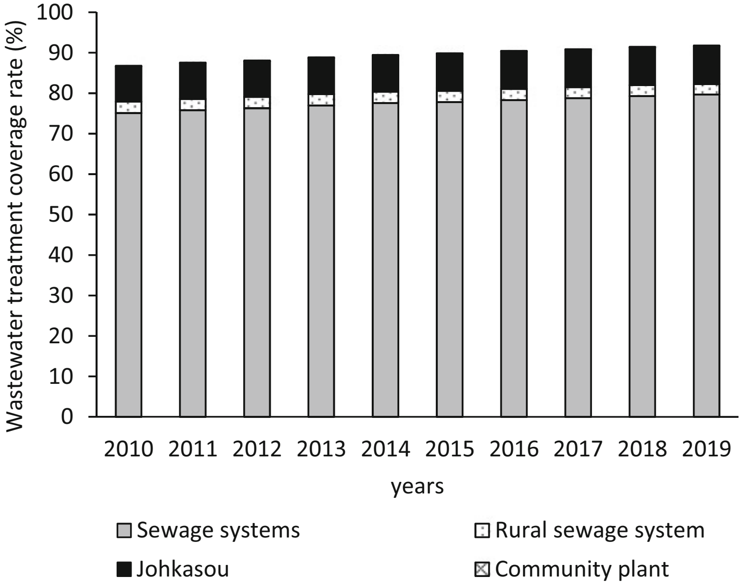


**Fig. 9.1** Wastewater treatment coverage rate in Japan (data from the Ministry of the Environment, Japan)

wastewater from the toilet is treated, and the other miscellaneous wastewater is discharged directly into the environment. Thus, installing new *tandoku-syori Johkasou* has been prohibited since 2001, and now only *gappei-syori Johkasou* are permitted to be installed.

Figure 9.1 shows the wastewater treatment coverage rate in Japan for the 10-year period from 2009 to 2019. In Japan, the wastewater treatment coverage rate is high; it reached 86.9% in 2010 and gradually increased to 91.7% in 2019. Out of these wastewater treatment systems, sewage systems are the most widespread, and their coverage rate increased from 75.1% in 2010 to 80.1% in 2019. In the case of rural sewage systems, the rate remains between 2.6 and 2.8%. For community plants, the rate has always been 0.2%, and there has been no significant change over the past 10 years. The rate of *Johkasou* usage was at 8.7% in 2010, and has gradually increased since then, reaching 9.3% in 2019. This indicates that *Johkasou* play an important role in household wastewater treatment in Japan.

The trend in the number of septic tanks installed in Japan from 2009 to 2019 is shown in Fig. 9.2. In 2010, the number of *tandoku-syori Johkasou* was larger than that of *gappei-syori Johkasou*, but in 2019, the number of *gappei-syopri Johkasou* installed exceeded that of *tandoku-syori Johkasou*. Installing new *tandoku-syori Johkasou* has been prohibited since 2001, indicating that the shift to *gappei-syori Johkasou* is progressing. However, there are still many *tandoku-syori Johkasou* in operation, and it is hoped that they will be transitioned to *gappei-syori Johkasou* as soon as possible.

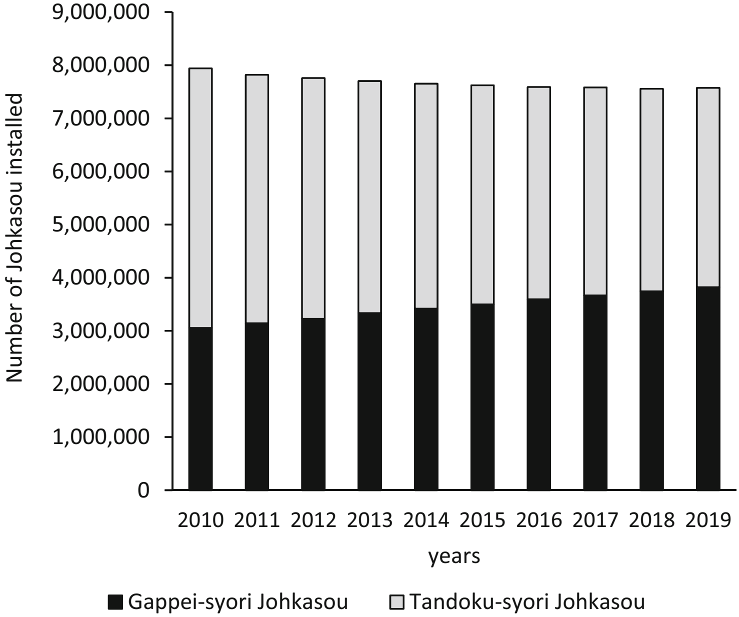


**Fig. 9.2** The number of *Johkasou* installed in Japan (data from the Ministry of the Environment, Japan)

## 9.3 Design and Management of *Johkasou*

### *9.3.1* Johkasou *Designs*

*Johkasou* are facilities that treat wastewater discharged mainly from toilets and gray water. They purify the wastewater to a certain level before the water is discharged. In this section, we explain small-scale *gappei-syori Johkasou*, which are mainly installed in houses.

The structure of *gappei-syori Johkasou* consist of features such as (1) an "anaerobic tank" where suspended solids in the wastewater settle and then anaerobic microorganisms decompose part of the organic matter, (2) an "aerobic tank" where air is blown in by a blower and aerobic microorganisms attached to the contact media decompose most of the organic matter, and (3) a "segmentation tank" where the sludge and supernatant contained in the treated water are separated.

The main body of the *gappei-syori Johkasou* structure is composed of fiberglass reinforced with plastic (FRP) and other materials and is manufactured in one piece at a factory. These types of *Johkasou* can be installed in the basement of each individual house parking lot and other spaces, and the treated water is then discharged into a channel or river. Their performance is equivalent to that of a sewage system, with an biochemical oxygen demand (BOD) removal rate of 90% or higher, and has a treated water quality of BOD 20 mg/L or lower (an advanced treatment type that can remove nitrogen and phosphorus is also available). As these types of facilities are important for conserving the aquatic environment, subsidies are available from the government, prefectures, and municipalities for their installation.

#### 9.3.1.1 Wastewater Treatment by *Johkasou*

The amount of domestic wastewater discharged from households is approximately 200 L per person per day, and it has a BOD load of approximately 40 g as pollutants. Of this, approximately 13 g of pollutants is discharged from toilets, and about 27 g of pollutants in gray water.

During the period of high economic growth in 1980, *tandoku-syori Johkasou* were widely used to treat wastewater from toilets. However, in this case, gray water discharged untreated, and the performance of the septic tanks themselves was not as good as that of today, so many pollutants were discharged into the environment. *Tandoku-syori Johkasou* were replaced by the development and widespread use of *gappei-syori Johkasou*, a technology unique to Japan that simultaneously treats wastewater from toilets as well as gray water. The "biological membrane method, "which has a high capacity to cope with temporal changes in wastewater load (quantity and quality), was applied to septic tanks, and the technology was established in the 1950s. Since then, improvements have been made, and technical progress has been made at a level comparable to other treatment facilities, such as sewage systems.

#### 9.3.1.2 Characteristics of *Gappei-Syori Johkasou*

*Gappei-syori Johkasou*, which are facilities that treat household wastewater, have the following features and are compared to a sewage system.

1. *Gappei-syori Johkasou* are installed where domestic wastewater is generated, and they treat and discharge wastewater on-site, so they do not require a network of pipelines to collect wastewater such as sewage systems.
2. In sewage systems, the discharge of treated water is concentrated at the discharge outlet of the wastewater treatment plant, resulting in large local changes in the river water volume. On the other hand, *gappei-syori Johkasou* do not cause large changes in water volume in local rivers and channels because only small volumes of domestic wastewater are treated on-site and then discharged.
3. Properly treated water can be used as emergency water during disasters. In addition, because industrial wastewater is not mixed in, the sludge contains less heavy metals and is easy to reuse.
4. When sewage systems are installed in cities with small populations, the cost per capita increases. On the other hand, *gappei-syori Johkasou* are mostly unaffected by this problem and can be efficiently maintained even in municipalities with small populations.

5. They are installed underground, are about the size of a car, and are not easily affected by the installation's location, topography, or geology.
6. *Gappeisyori Johkasou* are individually distributed facilities, and it is possible to make appropriate responses to changes such as a decrease in population.

#### 9.3.1.3 Types of *Gappei-Syori Johkasou*

There are various types of *gappei-syori Johkasou* that differ in their performance and treatment methods. For example, in addition to the standard BOD of 20 mg/L or less, there are those that can reduce BOD to 10 mg/L or less, or 5 mg/L or less, and there are also those that can remove nitrogen and phosphorus.

In addition, the "anaerobic filter bed and aerobic contact process" is the most widespread treatment method. However, there are also other methods, such as the "carrier fluidization and biological filtration system, "in which a "carrier fluidization section" and a "biological filtration section" are installed in place of the contact material in the "aerobic tank" to increase the treatment efficiency and reduce the overall capacity.

Small scale *gappei-syori Johkasou* are divided into units called "ninsou" in Japanese, which are based on the number of people in the home to be treated, and their size is determined according to the size of the house, such as "5 ninsou," "7 ninsou" or "10 ninsou." In areas that are not connected to a sewage system, large-scale *Johkasou* are sometimes used to treat wastewater from commercial and public facilities, some of which are large enough to serve more than 10,000 people. In this case, it is the same type of facility as a sewage system, but it is legally considered a *Johkasou*.

#### 9.3.1.4 Structure of the *Gappei-Syori Johkasou*

The *gappei-syori Johkasou* treatment mainly involves biological treatment using microorganisms, which is similar in principle to the treatment of wastewater in other wastewater treatment systems. A typical example of the treatment process in a septic tank is shown in Fig. 9.3.

1. Anaerobic tank

   In an anaerobic tank, suspended solids in the wastewater are usually precipitated and separated. Some of the pollutants in the wastewater are decomposed by anaerobic microorganisms (microorganisms that do not like oxygen). Depending on the model of the septic tank, the microorganisms are attached to filter media of various shapes to enhance the treatment.

2. Aerobic tank

   An aerobic tank is where aerobic organisms primarily carry out wastewater treatment. A blower sends fine bubbles of air to the bottom of the tank, and the

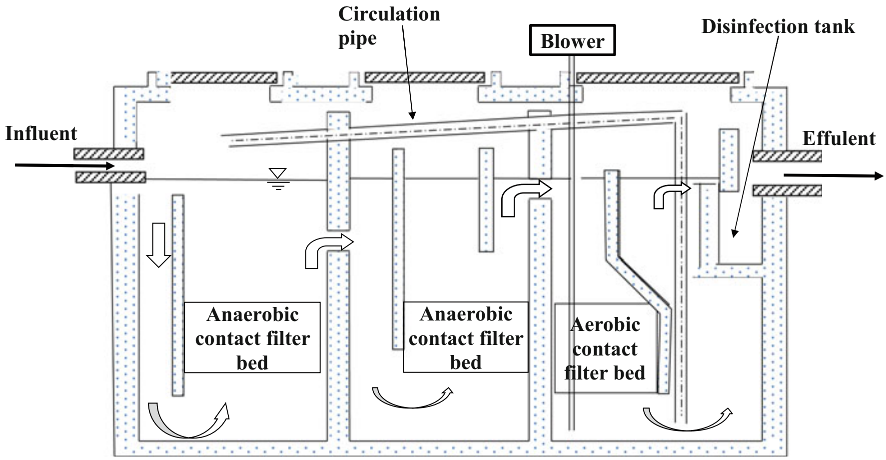


**Fig. 9.3** Schematic diagram of a *gappei-syori Johkasou* and treatment flow

biofilm of aerobic microorganisms attached to the surface of the contact filter medium decomposes the pollutants in the wastewater.

The activated sludge process, in which microorganisms are suspended, is the mainstream method in sewage systems, while the biological membrane process is the mainstream method used in *Johkasou*. Unlike the activated sludge process, the biological membrane process retains the sludge microorganisms in the reaction tank, resulting in less sludge return and the generation of less excess sludge by promoting self-oxidation.

3. Sedimentation tank

   In the sedimentation tank, sludge consisting of waste material such as proliferated microorganisms is sedimented and separated.

4. Disinfection tank

   The treated water is discharged after chlorination in the disinfection tank. In the disinfection tank, a plastic cylinder is filled with a tablet-type chlorine agent in the flow path, and the treated water meets the chlorine agent at the bottom of the cylinder and is disinfected.

In recent years, the structures used in *gappei-syori Johkasou* have been diversifying, and in addition to the conventional specifications set by the government (notified type), there are also compact types with smaller capacities (approximately 70%) and advanced treatment types with advanced nitrogen, phosphorus, and BOD removal in consideration of eutrophication in areas with strict water quality regulations (closed water bodies). Most newly installed *gappei-syori Johkasou* are equipped with a function to promote denitrification by transferring the treated water from the sedimentation tank to the anaerobic tank using an airlift pump.

## *9.3.2 Management of* **Johkasou**

*Johkasou* are facilities that use microorganisms to treat wastewater. Therefore, it is important to maintain an environment in which the microorganisms can actively work. If they are not managed properly, the function of the *Johkasou* will gradually deteriorate, degrading the aquatic environment and the surrounding habitat For this reason, administrators of *Johkasou* (users and installers) are required by *Johkasou* law to conduct periodic maintenance, desludging, and legal inspections.

### 9.3.2.1 Legal Inspections

Legal inspections are conducted to check whether the *Johkasou* have been installed correctly and are functioning properly. There are two types of inspections: water quality inspections after installation (legal inspection by Article 7) and periodic inspections (legal inspection by Article 11). According to the provisions in *Johkasou* law, only inspection bodies designated by the prefectural government (designated inspection bodies) are allowed to conduct legal inspections.

- Legal inspection by Article 7(Inspection after installation)
  This is an inspection stipulated by the provisions of Article 7 in *Johkasou* law. This type of inspection is conducted to ensure that the septic tank was properly installed and is functioning properly. It should be conducted during the first 3 to 8 months of use and aims to correct any problematic issues as soon as possible.
- Legal inspection by Article 11 (Periodic inspection)
  This is an inspection stipulated by the provisions of Article 11 in *Johkasou* law. Once a year, it must be confirmed that regular maintenance and cleaning is being carried out properly and that the septic tank is functioning normally.

### 9.3.2.2 Operation/Maintenance

Operation/maintenance maintains the normal functioning of the septic tank by checking whether each device and piece of machinery in the *Johkasou* is working normally, the operation process of the *Johkasou* as a whole, the treated water, the accumulation of sludge, and whether the pipes and filter media are clogged. *Johkasou* are facilities that treat wastewater using microorganisms; therefore, it is necessary to maintain an environment in which the microorganisms can thrive. In particular, the blower, which supplies oxygen to the microorganisms, needs to be checked because it operates continuously. In addition, consumables, such as disinfectants, need to be replenished and replaced periodically. Another important role of the operation/maintenance checks is to determine when to desludge and contact a *Johkasou* desludging vendor, if necessary. The frequency of operation/maintenance varies depending on the processing method and usage conditions, but it should be performed at least three times per year. Operation/maintenance must be carried out in accordance with the technical standards based on the Septic Tank Law. Maintenance and inspections must be entrusted to a contractor registered with the prefectural government.

#### 9.3.2.3 Desludging

Desludging is the process of removing the sludge and scum that accumulates in *Johkasou*, and cleaning and washing the attached equipment and machinery. In most cases, desludging is performed annually. Neglecting desludging can cause deterioration of the *Johkasou*, sludge leakage, and a bad odor.

## 9.4 Actual Usage of *Johkasou* and Original Efforts in Gifu Prefecture

Gifu Prefecture is located almost in the center of Japan, and the Hida region in the northern part of Gifu Prefecture has several mountains over 3000 m above sea level. In contrast, in the southern part of the prefecture, the Mino region, three major rivers—the Kiso River, the Nagara River, and the Ibi River flow through the Nono Plain. This section introduces a case study of wastewater treatment, the usage of *Johkasou* in Gifu Prefecture, and the original efforts made through cooperation among *Johkasou's* three different maintenance and management industry groups.

### *9.4.1 Current Status of Wastewater Treatment and Usage of* **Johkasou** *in Gifu Prefecture*

Figure 9.4 shows the wastewater treatment coverage rate in Gifu Prefecture over a 10-year period from 2009 to 2019. In Gifu Prefecture, the wastewater treatment coverage rate was 87.7% in 2010, and it gradually increased to 92.9% in 2019. This rate is slightly higher than that of Japan as a whole. For example, using 2019 as an example, the sewage systems coverage rate of Japan was 79.7%, while that of Gifu Prefecture was lower at 76.8%. As a result, rural sewage systems and *Johkasou* accounted for 5.6% and 10.7% of the total, respectively, which is slightly higher than that of Japan as a whole. This is probably due to topographical factors and the population distribution in Gifu Prefecture. This suggests that the role of *Johkasou* is comparatively more important in Gifu Prefecture.

The trend in the number of septic tanks installed in Gifu Prefecture for the 10-year period from 2009 to 2019 is shown in Fig. 9.5. From 2010 to 2019, the number *of gappei-syori Johkasou* increased and the number of *tandoku-syori Johkasou* decreased, indicating that the shift away from *tandoku-syori Johkasou* to

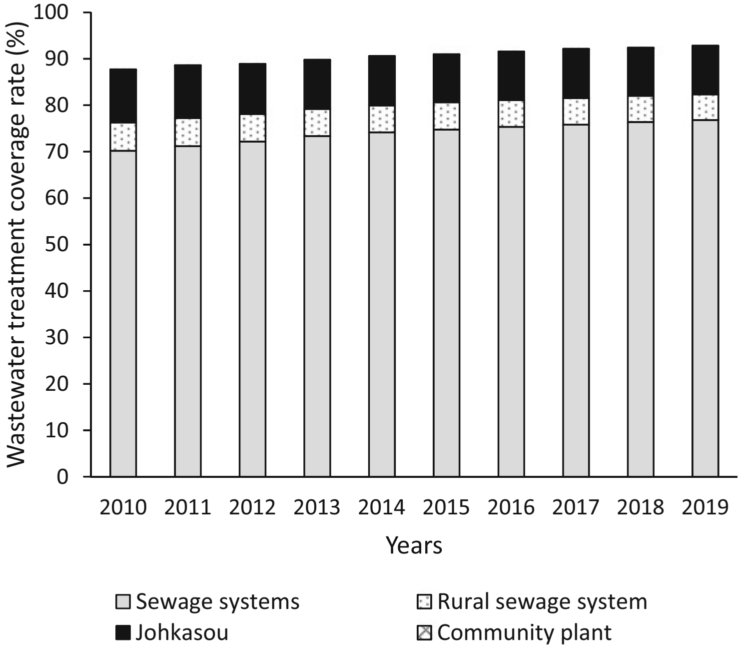


**Fig. 9.4** The wastewater treatment coverage rate in Gifu Prefecture (data from the Ministry of the Environment, Japan)

*gappei-syori Johkasou* has progressed. However, in Gifu Prefecture, the number of *tandoku-syori Johkasou* installed in 2019 still exceeded the number of *gappei-syori Johkasou* installed by 16,000, indicating that the shift to *gappei-syori Johkasou* was delayed compared to the rest of Japan. In Gifu Prefecture, it is anticipated that there will be a faster shift to *gappei-syori Johkasou* in the future.

## *9.4.2 Original Efforts in Gifu Prefecture*

### 9.4.2.1 "Water Reclamation Facilities" Recognition System for *Johkasou*

The "Water Reclamation Facilities Recognition System for *Johkasou*" was launched in April 2007 to certify excellent *gappei-syori Johkasou* are undergoing advanced maintenance and management (Akabane et al. 2014, Watanabe 2014). Under this system, a legal inspection agency designated by Gifu Prefecture certifies that *gappei-syori Johkasou* conforms to a stricter standard (treated wastewater transparency of 30°) than the Ministry of the Environment's guideline (treated wastewater transparency of 20°) and is a facility equivalent to a sewage system. *Gappei-syori Johkasou*,

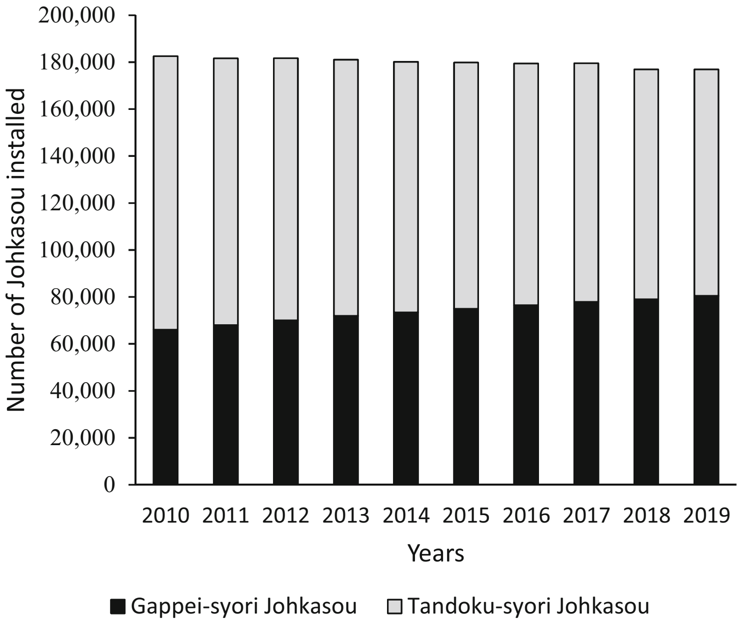


**Fig. 9.5** The number of *Johkasou* installed in Gifu prefecture (data from the Ministry of the Environment, Japan)

which complied with the recognition standards for the past three consecutive years, are recognized as "Water Reclamation Facilities."

The following four criteria must be met to be recognized.

1. Compliance with the judgment criteria for the past three consecutive years in legal inspections, including inspections by Articles 7 and 11, conducted by the Gifu Environmental Management Technology Center.
2. Operation/maintenance and desludging were carried out in accordance with the frequency and technical standards specified in *Johkasou* law.
3. The treated water must have a transparency of 30°or higher.
4. An alarm is installed to notify someone when the blower has stopped.

As of November 2021, 61,323 *gappei-syori Johkaso*u have been recognized. When a septic tank is certified under this system, a seal of recognition is affixed to the home by the *gappei-syori Johkasou* installer, and there is no fee to apply for this designation.

#### 9.4.2.2 Cooperation among *Johkasou*'s Three Different Maintenance and Management Industry Groups

The maintenance and management industry groups of *Johkasou* in Gifu Prefecture have set the standard for treated water quality at a transparency of 30° or higher. A transparency of 30° is approximately equal to 13 mg/L or less in BOD, which is equivalent to or higher than the BOD discharge standard of sewage systems. In addition, the guidelines for the maintenance and management of *gappei-syori Johkasou* state that the desirable range of water transparency is 30 cm or more because the probability of the BOD being over 20 mg/L is extremely high if the transparency of the effluent is 30 cm or more. A certain degree of transparency in the treated water has been ensured in the maintenance of *Johkasou* without coordination among the three operation/maintenance, desludging, and legal inspection organizations. However, in order to achieve a higher transparency of the treated water, *Johkasou's* three different maintenance and management industry groups in Gifu Prefecture have established an effective and efficient *Johkasou* maintenance and management system by using tablet computers to "send-off" and share information (Murai et al. 2014, Watanabe 2014). As a result of this effort, the ratio of *Johkasou's* with a treated water transparency 30° or higher increased from 76.0% in 2007 to 92.2% in 2017.

## 9.5 Effect of *Johkasou's* Operational Conditions on the Quality of the Treated Water

As mentioned in the previous section, the goal for the treated water as designated by the association involved in the on-site maintenance of *gappei-shori Johkasou* is above 30° of transparency in Gifu Prefecture. However, approximately 8% of the *gappei-shori Johkasou* did not meet this maintenance goal.

This section introduces a part of the research on the operating conditions that the contractor can set during the maintenance and cleaning of *gappei-syori Johkasou* to improve the quality of the treated water (Ishiguro et al. 2016, 2017, 2017b, 2018). In this section, unless otherwise noted, "*Johkasou*" is used to refer to "*gappei-syori Jophkasou*."

### *9.5.1 Effect of Water Circulation on the Quality of the Treated Water*

Three small-scale *gappei-syori Johkasou* models with nitrogen removal functions that were operating in ordinary households in Gifu Prefecture were selected for this study. *Johkasou* use a contact filter bed system and have the following treatment

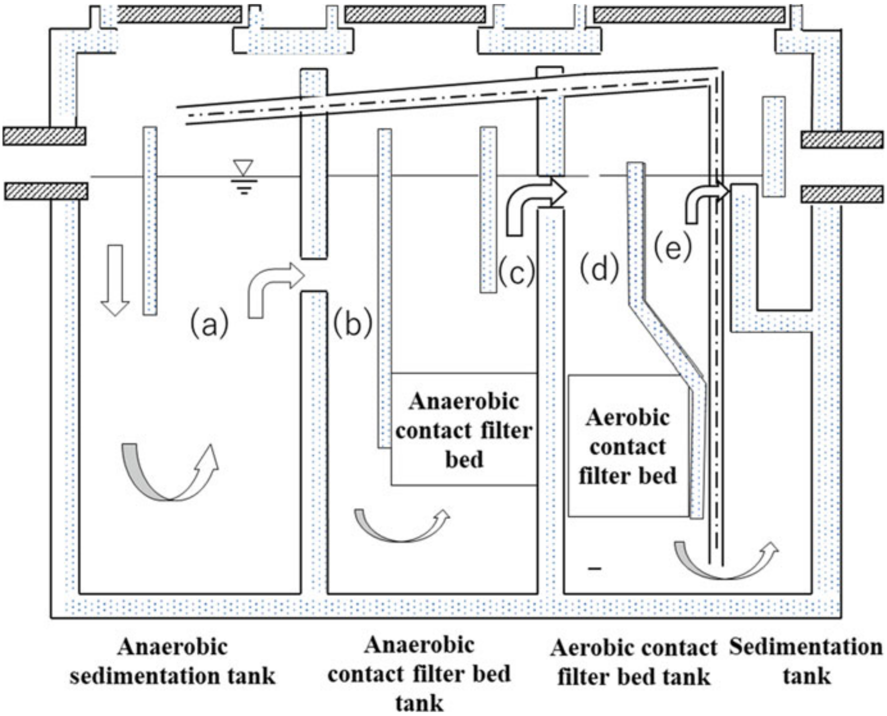


**Fig. 9.6** Flowchart of the studied *Johkasou* and sampling points for water collection. (**a**) water in the anaerobic sedimentation tank, (**b**) inlet water of the anaerobic contact filter bed tank, (**c**) outlet water of the anaerobic contact filter bed tank, (**d**) water in the aerobic contact filter bed tank, and (**e**) water in the sedimentation tank

performance: BOD = 20 mg/L or less, total nitrogen = 20 mg/L or less, and suspended solids (SS) = 20 mg/L or less. Wastewater is treated in four tanks: an anaerobic sedimentation tank, an anaerobic contact filter bed tank, an aerobic contact filter bed tank, and a sedimentation tank; the treated water is then chlorinated in a disinfection tank before being discharged. (Fig. 9.6). The anaerobic contact filter bed tank is equipped with a filter filled with skeletal-like spherical anaerobic filter media. The aerobic contact filter bed tank remains aerobic, and constant aeration is performed using a blower. In the aerobic contact filter bed tank, plate-like filter materials are installed at the top, and net-like cylindrical filter materials are installed at the bottom. The circulating water was returned from the bottom of the sedimentation tank to the anaerobic sedimentation tank using a circulating airlift pump.

This case study was conducted from April 23 to August 27, 2015. During the study period, the circulating water volume of the treated water circulation was varied to investigate the effect of water circulation on the treated water quality, and the relationship between the two was analyzed using multivariate analysis. Surveys were conducted once a week, and water samples were collected from five locations (a)–(e), as shown in Fig. 9.6.

Dissolved Oxygen (DO), pH, and redox potential (ORP) were measured at the sampling sites, and the circulating water volume, the scum thickness in each tank, and the sludge thickness in each tank were also measured. The circulating water volume was measured at the outlet of the circulation pipe in the anaerobic sedimentation tank.

Turbidity, suspended solids (SS), volatile suspended solids (VSS), biochemical oxygen demand (BOD), carbonaceous biochemical oxygen demand (C-BOD), dissolved organic carbon (DOC), total nitrogen, ammonia nitrogen, nitrite-nitrogen, nitrate-nitrogen, and total phosphorus were measured in the laboratory.

Figure 9.7 shows the changes in BOD, total nitrogen, and total phosphorus in one of the three *Johkasou* surveyed as an example. BOD without circulation (WCR: 0; WCR means the water circulation ratio) was high in the water of the anaerobic sedimentation tank and the inlet water of the anaerobic contact filter bed tank, and low in the outlet water of the anaerobic contact filter bed tank, the water in the aerobic contact filter bed tank, and in the water in the sedimentation tank (Fig. 9.7a). The BOD in the water in the anaerobic sedimentation tank and in the inlet water of the anaerobic contact filter bed tank decreased with a water circulation ratio of 3 (WCR: 3), in which the water in the sedimentation tank was returned to the anaerobic sedimentation tank at three times the daily average inflow water volume rate, and at a circulation ratio of 2 (WCR: 2), in which the water in the sedimentation tank was returned at two times the daily average inflow water volume rate. However, there was no significant difference in the BOD of the water in the sedimentation tank.

Total nitrogen was high in the water in the anaerobic sedimentation tank without circulation (WCR 0), but it decreased in WCR 3 and WCR 2. In addition, the total nitrogen in the water in the sedimentation tank showed a tendency to decrease in WCR3 and WCR2 compared to the WCR 0. The pattern of total phosphorus was similar in all tanks with and without water circulation, and no increase or decrease was observed with water circulation (Fig. 9.7c).

A decrease in total nitrogen due to the change in water circulation in the three tanks suggests that nitrate-nitrogen produced by nitrification in the contact filter bed tank is returned to the impurity removal tank by circulating water (Fujimura and Nakajima 1998), resulting in denitrification and consequently a decrease in total nitrogen in the water in the treatment tank.

Due to the circug water, a clear change in BOD was observed in the primary treatment (the anaerobic sedimentation tank and anaerobic contact filter bed tank). In contrast, the BOD of water in the aerobic contact filter bed tank and the water in the sedimentation tank did not increase, even though water with a high pollution load was pushed out to the secondary treatment (the aerobic contact filter bed tank and the sedimentation tank) by circulating water. This suggests that the organic matter removal performance was maintained in the secondary treatment, which could remove the organic matter that flowed in from the primary treatment.

Figure 9.8 shows the results of the cluster analysis and Fig. 9.9 shows the results of the principal component analysis of water in the sedimentation tank of a

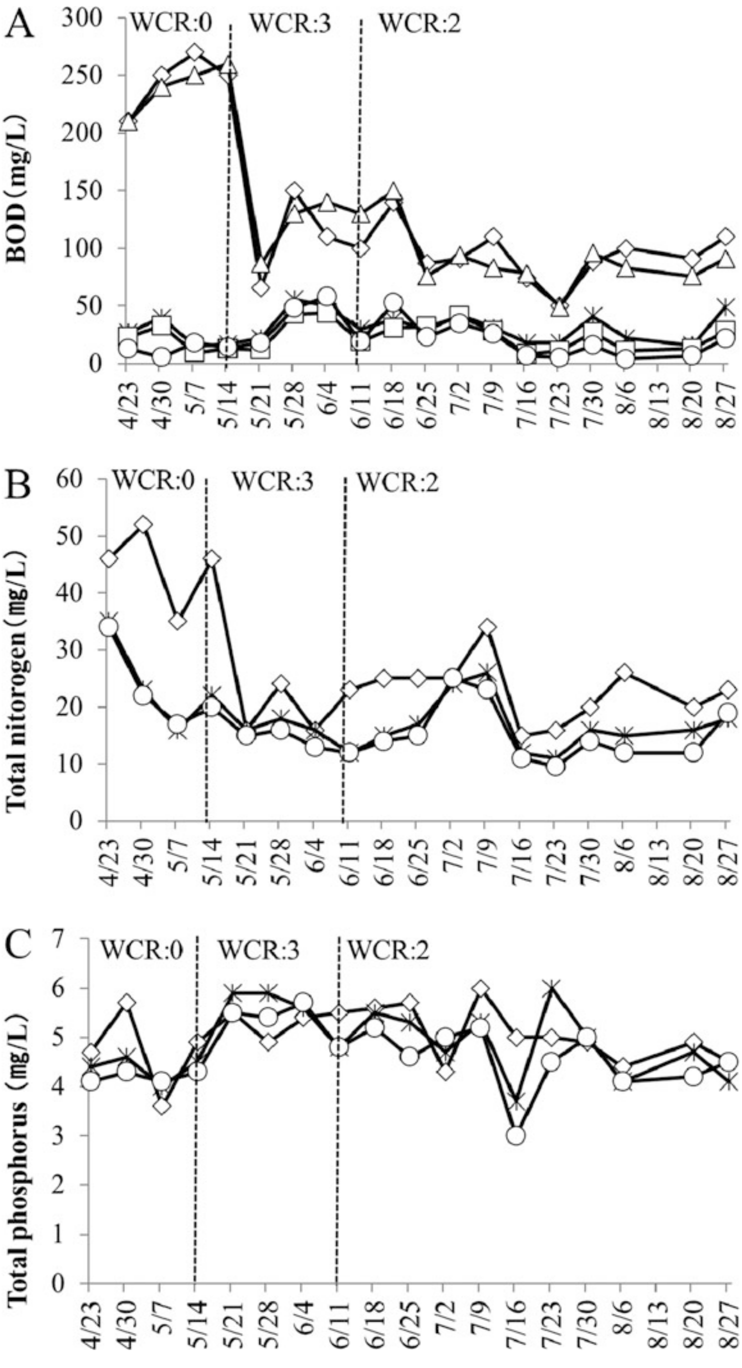


**Fig. 9.7** Changes in biological oxygen demand (BOD), total nitrogen, and total phosphorus due to circulation changes in the treated water. (◇) Water in the anaerobic sedimentation tank, (△) inlet water of the anaerobic contact filter bed tank, (*) outlet water of the anaerobic contact filter bed tank, (□) water in the aerobic contact filter bed tank, and (○) water in the sedimentation tank. WCR

*Johkasou,* as examples of the multivariate analyses. In the cluster analysis (Fig. 9.8), the data were classified into three clusters by a coupling distance of 2.0 or less.

When the results of principal component analysis and cluster analysis were combined, SS, VSS, and organic nitrogen were included in the index that constituted cluster I and had the highest degree of correlation with the first principal component axis, along with BOD, C-BOD, and turbidity.

These results indicate that suspended organic matter is strongly related to BOD, C-BOD, and turbidity. Total nitrogen, ammonia nitrogen, pH, and nitrate nitrogen, which constitute clusters II and III and have a high degree of correlation with the second principal component axis, are a group of indices related to denitrification and nitrification.

The loadings expressed by BOD, C-BOD, SS, VSS, and organic nitrogen were similarly distributed in the three *Johkasou* and could be grouped together. In addition, total phosphorus was included in the same group. In contrast, DOC was grouped into a different group from BOD and C-BOD in all *Johkasou*. These results indicate that suspended organic matter is strongly related to the organic load (BOD and C-BOD).

However, ammonia nitrogen, nitrate-nitrogen, total nitrogen, pH, and ORP were considered to be related to nitrification and denitrification.

The indexes that made up these two groups were grouped together on the first and second principal component plane without mixing, indicating that the relationship between these groups was low.

These results suggest that, when considering improvements made to the treated water from *Johkasou*, there is little relationship between the nitrogen load and the organic load represented by BOD and C-BOD. Therefore, water circulation is effective for nitrogen removal; however, other measures should be considered for reducing the organic load.

### *9.5.2 Effect of Aeration Rates on the Treated Water*

Eleven *Johkasou*, the same type as those surveyed in Section 4.1, were among those surveyed in houses in Gifu Prefecture, and did not meet the required water transparency of 30°. The effect of the aeration volume on the treated water was investigated by changing the aeration volume setting based on the DO of the water in the aerobic contact filter bed tank and the sedimentation tank in each *Johkasou*. The relationship between aeration volume and treated water quality was analyzed using multivariate analysis.

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**Fig. 9.7** (continued) means the water circulation ratio, that is, the circulation water volume/influent water (reproduced from Ishiguro et al. 2016)

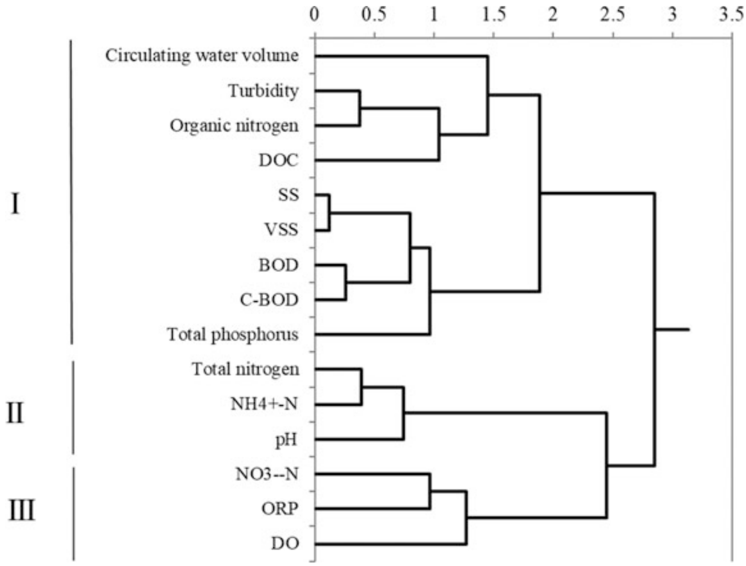


**Fig. 9.8** Cluster analysis results for water samples in a sedimentation tank under the influence of circulating water (reproduced from Ishiguro et al. 2016)

A field survey and sample collection were conducted on the first day of the survey, and the aeration volume of the aerobic contact filter bed tank was changed.

Four weeks after the setting change, a field survey and sample collection were conducted. If the transparency of the treated water was improved to 30° or higher, the survey was deemed complete. If the transparency of the treated water did not meet 30°, the aeration volume was changed. In addition to the indices described in Section 4.1, the number of particles, the sludge volume index (SVI) of the sludge in the sedimentation tank, and the amount of biofilm attached to the contact material in the aerobic contact filter bed tank were measured.

As a result of changing the aeration volume of the aerobic contact filter bed tanks, the transparency of the treated water in three *Johkasou* increased to more than 30°, and the BOD decreased with the increasing aeration volume. In six *Johkasou*, decreasing the aeration volume of the aerobic contact filter bed tanks increased the transparency of the treated water to more than 30° and decreased the BOD. The total nitrogen and total phosphorus did not show a constant trend with changing aeration volume. These results suggest the possibility of reducing the organic load by increasing the aeration volume.

The results of the cluster analysis and principal component analysis of the sedimentation tank are shown in Figs. 9.10 and 9.11, respectively.

In the cluster analysis, four clusters were formed when the bond distance was less than 2.0.

The results of the cluster analysis (Fig. 9.10) and principal component analysis (Fig. 9.11) showed that total BOD and C-BOD were linked to turbidity, organic

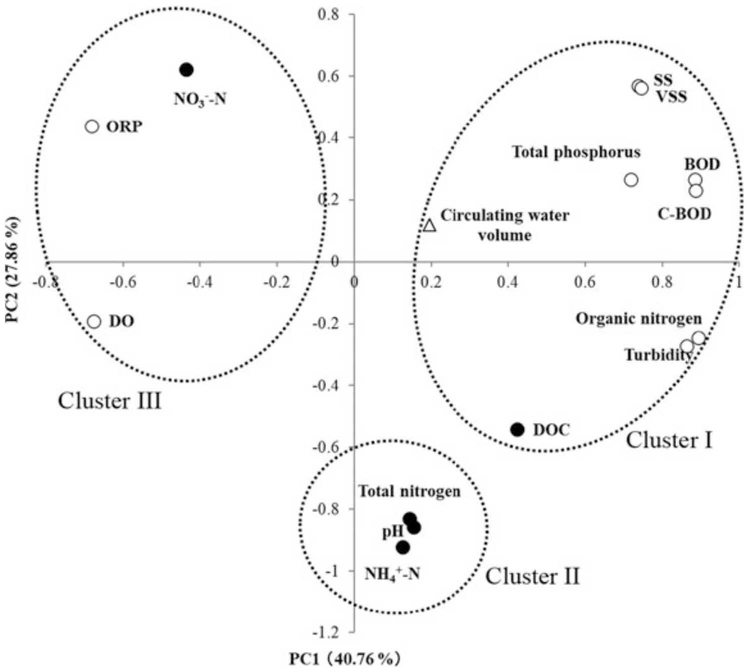


**Fig. 9.9** Principal component analysis results for water samples in a sedimentation tank under the influence of circulating water. (○)The first principal component, (●)the second principal component, and (△) the third principal component, with the highest loading values (reproduced from Ishiguro et al. 2016)

nitrogen, SS, VSS, and particles with sizes from 0.5–1 μm. The results of the principal component analysis also showed a close link between aeration volume and these water quality indices.

The results suggest that increasing the aeration volume is one way to improve the quality of the treated water in *Johkasou*. In addition, we suggest that particles with sizes from 0.5–1 μm are related to the quality of the treated water, especially to the organic loading.

### *9.5.3 Small Particles Are Related to Treated Water Quality*

To investigate how small particles are related to the treated water quality in detail, water in the sedimentation tanks of *Johkasou*, whose transparency increased from 10° to 83° by increasing the aeration volume of the aerobic contact filter bed tank from 30 L/min to 63 L/min, was placed onto a filter, freeze-dried, platinum-deposited, and then observed with a scanning electron microscope (Fig. 9.12). A large number of bacteria-like substances were observed in the water that had a

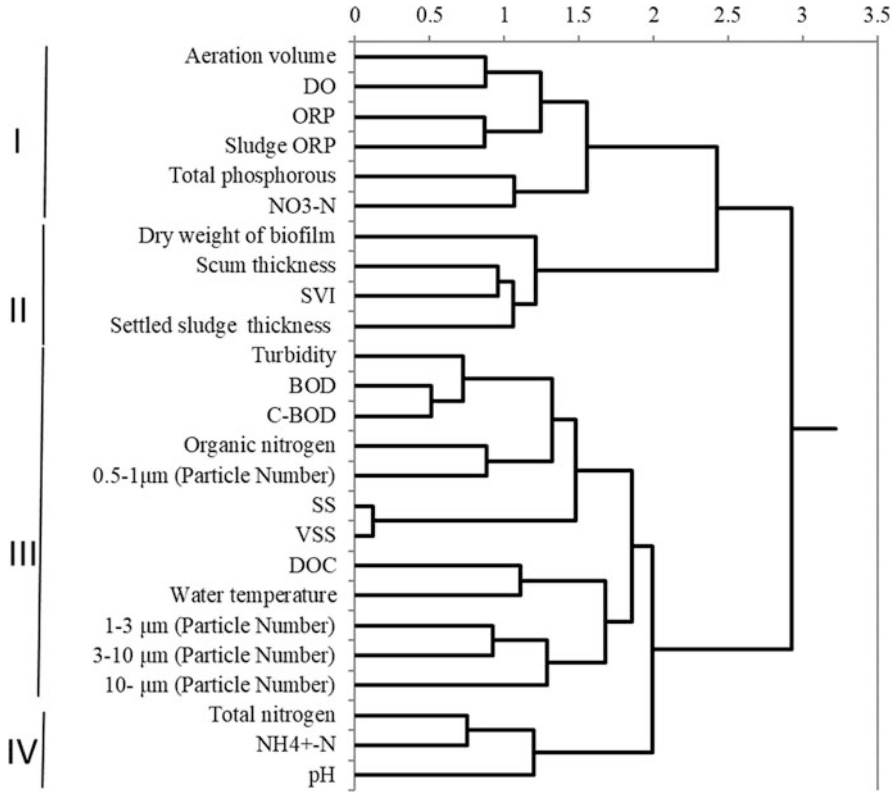


**Fig. 9.10** Cluster analysis results for water and sludge samples in the sedimentation tank. (reproduced from Ishiguro et al. 2017b)

transparency of 10° (left side of Fig. 9.12). On the other hand, although bacteria-like substances were also present in the water in the treatment tank that had 83° of transparency, the amount of bacteria-like substances was clearly lower (right side of Fig. 9.12).

The number of bacteria was measured using a flow cytometer (Fig. 9.13). There was a large difference in the number of bacteria in the outlet water of the anaerobic contact filter bed tank, the water in the aerobic contact filter bed tank, and the water in the sedimentation tank. The number of bacteria in the sedimentation tank was lower at an aeration volume of 63 L/min and a transparency of 83° compared to an aeration volume of 30 L/min and a transparency of 10°. Furthermore, there was a significant correlation between the number of bacteria and the reciprocal of the water transparency of the water collected from the sedimentation tank (Fig. 9.14). This suggests that the bacteria in the treated water are related to the quality of the treated water, especially the organic load.

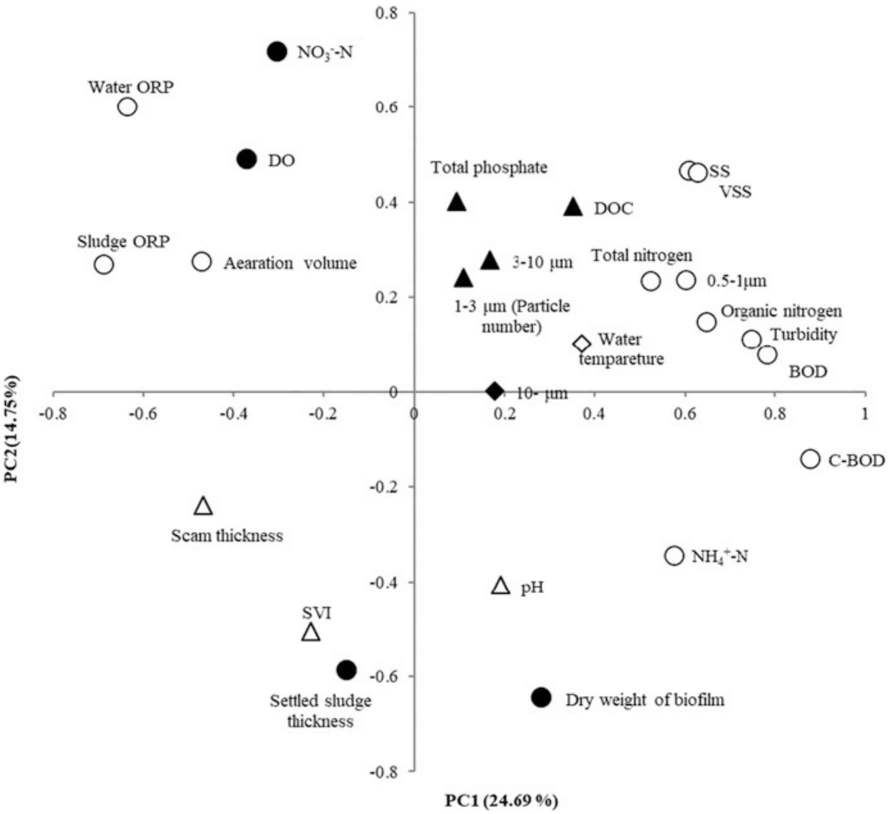


**Fig. 9.11** Principal component analysis of the water and sludge samples collected from the sedimentation tank. (○) The first principal component, (●) the second principal component, (△) the third principal component, (▲) the fourth principal component, (◇) the fifth principal component, and (◆) the sixth principal component with the highest loading values (reproduced from Ishiguro et al. 2017b)

## 9.6 Conclusion

*Johkasou* are excellent on-site wastewater treatment systems that were developed and are widely used in Japan. They are small wastewater treatment facilities that mainly treat wastewater in households. They are responsible for about 10% of the wastewater treatment in Japan and support a clean and comfortable living environment and preserve the natural environment. However, the treatment performance of *Joukasou* vary depending on their type, conditions of usage, and state of maintenance and inspection, and this affects the quality of the treated water. Treated water from *Johkasou* is discharged into natural water bodies such as rivers and lakes in a dispersed manner through ditches and waterways, thus greatly affecting the environment of the river basin. Therefore, *Johkasou* must be properly maintained and

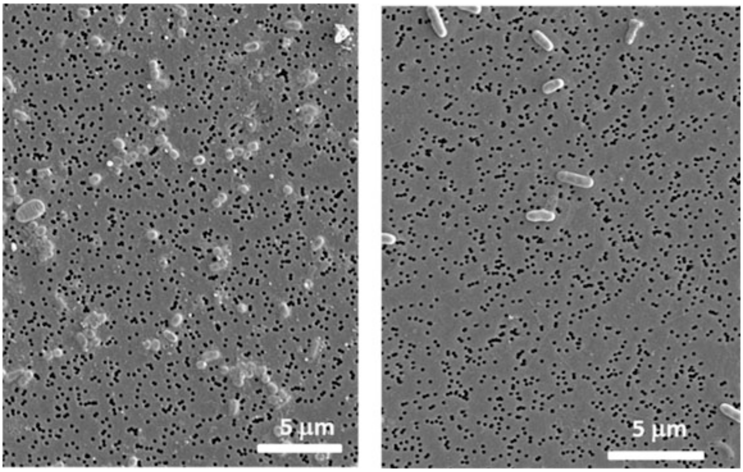


**Fig. 9.12** Small particles in the water collected from the sedimentation tank and observed with a scanning electron microscope. Left: aeration volume of 30 L/min and a transparency of 10°. Right: aeration volume of 63 L/min and a transparency of 83° (reproduced from Ishiguro et al. 2017b)

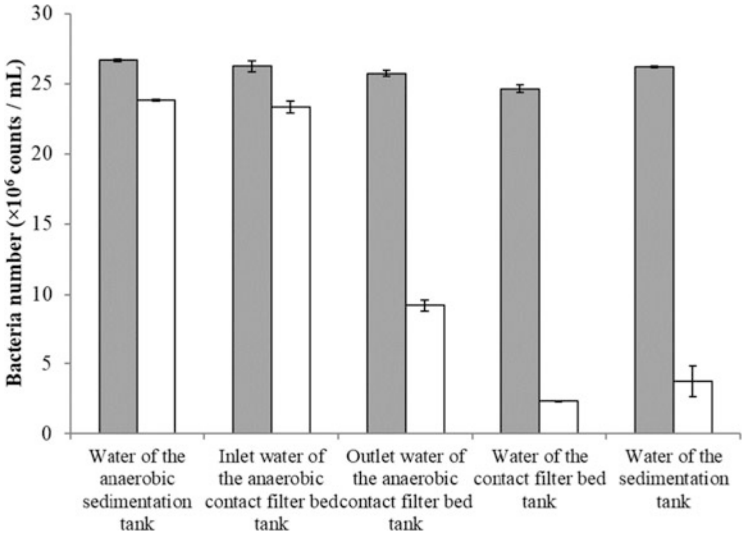


**Fig. 9.13** Change in the number of bacteria within change the aeration volume. : Aeration volume of 30 L/min and a transparency of 10°. : Aeration volume of 63 L/min and a transparency of 83°. The bars indicate the standard deviation (reproduced from Ishiguro et al. 2017b)

managed. In our study, we presented some suggestions that can be used in the maintenance and management of *Johkasou*.

In the future, we anticipate that the installation of *gappei-syori Johkasou* will become more widespread in areas that have not yet been connected to public sewage

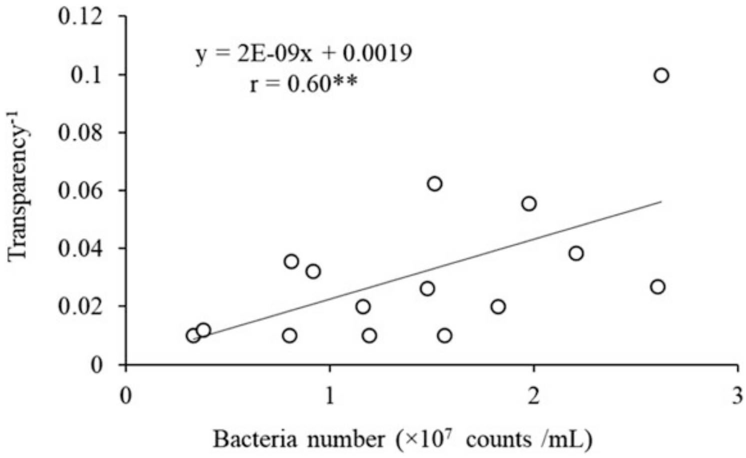


**Fig. 9.14** Relationship between the number of bacteria and the reciprocal of the water transparency in the water collected from the sedimentation tank. **P < 0.05 (reproduced from Ishiguro et al. 2017b)

systems and that this will help preserve the environment of the surrounding river basin. In addition, we will continue to study the maintenance and management of *Johkasou*.

**Acknowledgments** We would like to express our gratitude to the Gifu Environmental Management Technology Center for their extensive cooperation in sampling and conducting the research. We would like to thank Editage (www.editage.com) for English language editing.

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