Social Integration and Acceptance of Emerging Sanitation Infrastructure in Japan

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Chapter 11
Social Integration and Acceptance of Emerging Sanitation Infrastructure in Japan

Taku Fujiwara

Abstract Availability and sustainable management of the sewerage system are extremely important as sanitation infrastructure to achieve Sustainable Development Goal 6. Japan has become a depopulated society since 2010, and therefore sewerage systems in Japan will face difficulties because of the decrease in human resources, deterioration of the facilities, and limited budgets. Although innovative sanitation technologies to overcome these issues are strongly required, various barriers inhibit the development, implementation, and technology diffusion. The author and his research group have developed "dual dissolved oxygen control system in oxidation ditch process" through three-way university–industry–government partnerships. This chapter summarizes the history of the development, social acceptance, and expansion to other cities of the technology and analyzes the social integration and acceptance process. The key elements behind the success of this project are as follows: (1) enthusiasm of all stakeholders toward the shared goal, (2) win-win relationships among stakeholders and respect for each other, (3) research and development considering future applications and technology diffusion, (4) participation of local governments as important stakeholders, (5) agreement of the municipal parliament of Konan City, and (6) registration of the technology to "JS Innovation Program," by Japan Sewage Works Agency.

Keywords Dual dissolved oxygen control system · Emerging sanitation infrastructure · Social integration and acceptance · Technology diffusion · Three-way university–industry–government partnerships

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11.1 Introduction

The United Nations announced 17 Sustainable Development Goals (SDGs) and 169 Targets as part of its 2030 Agenda for Sustainable Development, a plan of action seeking to strengthen universal peace and human prosperity (UN 2015). Goal 6 aims to "ensure availability and sustainable management of water and sanitation for all." The COVID-19 pandemic has highlighted the critical importance of water, sanitation, and good hygiene practices for protecting human health (UN 2020). Safe management of the sanitation infrastructure is crucial for protecting the health of individuals and drinking water sources, as indicated by Target 6.2 (UN-Water 2017). Target 6.3 aims to "improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally" (UN-Water 2017). The sewerage system is an important sanitation infrastructure from the viewpoints of Targets 6.2 and 6.3, and the availability and sustainable management of the system are of great importance.

Japan became classified as a depopulated society in 2010 (Statics Bureau of Japan 2015), despite the fact that the global population is projected to increase until 2100 according to the World Population Prospects 2019 (median value) (UN 2019). It is expected that sewerage systems in Japan will encounter difficulties due to the decrease in human resources, deterioration of the facilities, and limited budgets. Considering likely future situations in Japan, the simple replacement of sewerage systems is not acceptable, and innovative technologies that allow for sustainable management should be developed. However, various barriers may inhibit such innovation. Through a content analysis of 195 articles, Galvão et al. (2018) identified the following main barriers to the implementation of a circular economy: (a) technological, (b) social, (c) policy and regulatory, (d) managerial, (e) financial and economic, (f) customer, and (g) performance indicator (Galvão et al. 2018).

The author and his research group have developed an innovative sanitation technology, a dual dissolved oxygen (DO) control system in the oxidation ditch (OD) process, through three-way university–industry–government partnerships. Fundamental research was initiated at Kochi University with undergraduate students using lab-scale reactors and synthetic wastewater. The research was then upscaled to bench-scale experiments using real wastewater, and finally applied to full-scale demonstrations at the Noichi wastewater treatment plant (WWTP) in Konan City, in Kochi Prefecture, Japan. After a successful full-scale demonstration, Konan Municipal Government modified the overall sewerage system plan by integrating the 10 WWTPs into two WWTPs in which the developed technology was installed. This modification is expected to save about 400 million JPY and contribute to the sustainable management of the sewerage system in the city (Editorial Department of Journal of Sewerage, Monthly 2020). This system was expanded to nine WWTPs in Japan (as of July 2021) and awarded by the Ministry of Land, Infrastructure, Transport and Tourism, Japan (MLIT), Japan Society on Water Environment

(JSWE), Japan Science and Technology Agency (JST), and the Japan Society of Industrial Machinery Manufacturers (JSIM).

The objective of this chapter is to examine the history of the technological development, social acceptance, and expansion to other cities of the "dual dissolved oxygen control system in oxidation ditch process" and to analyze the social integration and acceptance process of this emerging sanitation infrastructure.

11.2 Development of an Emerging Sanitation Technology Through Three-Way University–Industry–Government Partnerships

11.2.1 The OD Process

The OD process is an extended aeration-activated sludge system that treats sewage from small- and medium-sized communities. The typical OD process consists of an oval- or horseshoe-shaped channel with mechanical aerators that simultaneously provides circulation and oxygen supply to the ditch and a final clarifier that returns activated sludge to the ditch. The primary clarifier is not typical of the system. Figure 11.1 presents a photo of the horseshoe-shaped channel of an OD process in Japan. The United States Environmental Protection Agency published the "Wastewater Technology Fact Sheet for Oxidation Ditches" and showed a common influent biochemical oxygen demand (BOD) loading rate of 0.24 (kgBOD/m^3 day) and hydraulic retention time (HRT) ranging from 6 to 30 h (United States Environmental Protection Agency 2000a). The OD process was designed and operated at a longer HRT from 24 to 36 h in Japan (Japan Sewage Works Association 2019). Japan

Fig. 11.1 Oxidation ditch at Yasu WWTP, Konan, Japan. (Photo: provided by Maezawa Industries, Inc.)

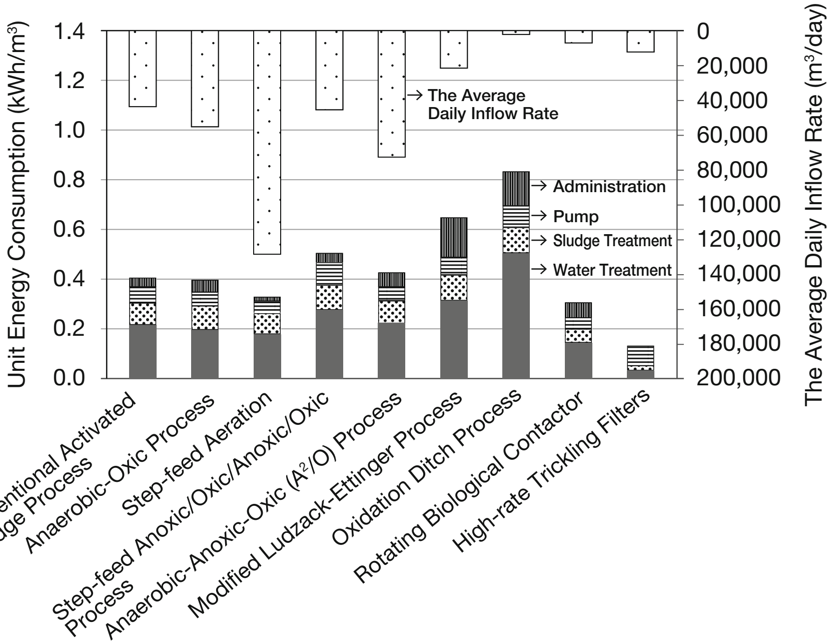

Fig. 11.2 Unit energy consumption for various wastewater treatment processes in Japan. (Reprinted with modification from the Japan Institute of Wastewater Engineering and Technology 2014 with the permission of JIWET)

Sewage Works Agency (JS) reported that average effluent concentrations of BOD and suspended solids were less than 4 and 5 mg/L, respectively, while average total nitrogen (T-N) removal efficiency was about 75% for the OD process (Japan Sewage Works Agency 2000). It also proposed appropriate aerobic sludge retention time and the aerobic/anoxic time ratio for obtaining more than 85% of T-N removal (Japan Sewage Works Agency 2000). Figure 11.2 illustrates the average values of unit energy consumption for various wastewater treatment processes in Japan (Japan Institute of Wastewater Engineering and Technology 2014). The unit energy consumption for water treatment of an OD process is about 0.5 kWh/m^3, which is 2.5 times higher than that for a conventional activated sludge system. Indeed, the OD process is an extended aeration-activated sludge system for small- and medium-sized communities with easy operation and maintenance and good effluent water quality. However, high energy consumption should be brought under control for reducing the cost and mitigating greenhouse gas emissions.

11.2.2 Outline of the Dual DO Control System in the OD Process

The dual DO control system in the oxidation ditch process is depicted in Fig. 11.3. Flow boosters with 16 vertical blades are installed at the bends in the OD and are rotated slowly to generate an ideal plug flow. Compressed air from the root blowers is introduced from the membrane diffusers at the straight segment of the ditch to supply oxygen to the activated sludge. Two DO sensors are installed to control the DO gradient in the ditch. The first DO sensor (DO sensor 1) is placed immediately downstream of the aeration units to control the aeration intensity, while the second DO sensor (DO sensor 2) is set at the end of the aerobic zone to control the flow rate in the ditch by changing the rotation speed of the flow boosters. As a result, the dual DO control system automatically regulates the aerobic/anoxic zone ratio in the ditch under large fluctuations in influent loading. Organic compounds in the influent wastewater are decomposed by aerobic respiration in the aerobic zone and denitrification in the anoxic zone. Ammonia in the influent is oxidized to nitrite and nitrate in the aerobic zone; thereafter, oxidized nitrogen is denitrified to nitrogen gas in the anoxic zone. Hence, the balance of aerobic and anoxic zones in OD systems is of great importance for the simultaneous removal of organics and nitrogen from influent wastewater. In addition, energy savings are achieved through the optimization of the aeration and rotation speed of the flow boosters. The JS registered the dual DO control system in the OD process in the JS Innovation Program. The benefits of this technology are summarized as follows (Japan Sewage Works Agency 2014):

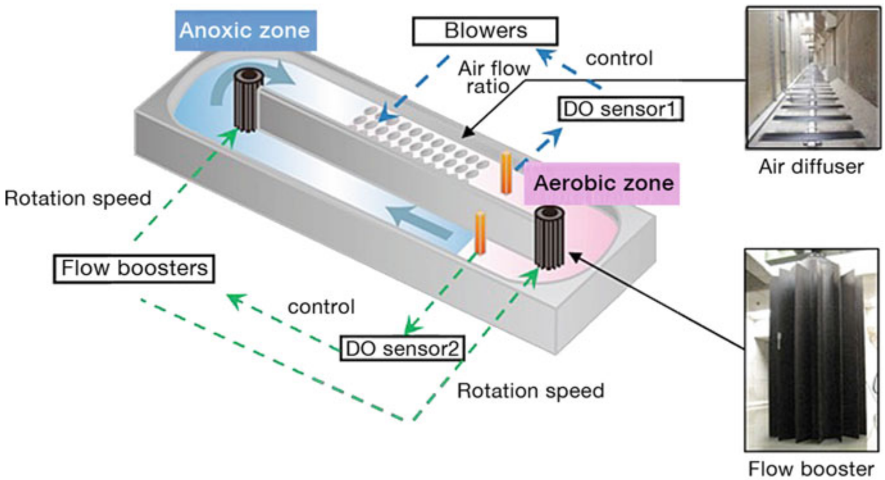

Fig. 11.3 Schematic diagram of dual dissolved oxygen control system in the oxidation ditch process. (Provided by Maezawa Industries, Inc.)

- Stable effluent quality of biochemical oxygen demand (BOD) and nitrogen.
- Reduction in power consumption by 30% compared to conventional OD equipped with vertical shaft aerators.
- Adaptable to high-load operation, such as a temporal excess inflow or high concentration of BOD and nitrogen in influent sewage.

11.2.3 History of Technological Development: From the Origin to the Full-Scale Demonstration

The history of the research, development, and dissemination of the dual DO control system in the OD process is summarized in Table 11.1. The origin of this research is the author's doctoral thesis entitled "Application study of a draft-tube-type reactor to nitrification-denitrification process" published in 1999. The draft-tube-type reactor realized simultaneous nitrification and denitrification by creating both aerobic and anoxic zones in a single reaction tank, and the design and operational parameters were presented in several publications (Fujiwara 1999; Fujiwara et al. 1998). After earning a doctoral degree at Kyoto University, he moved to Kochi University and started lab-scale experiments for the OD process in 2000. He considered that operation at a shorter HRT increases the oxygen consumption rate of activated sludge and enables the control of the DO gradient more easily based on research experience during his doctoral course. He also conducted a theoretical analysis and clarified that the DO recirculation rate is an important operational parameter. The author and his research group experimentally proved that the DO recirculation rate is

Table 11.1 History of research, development, and dissemination for dual dissolved oxygen control system in the oxidation ditch process

FY	Remarks
2000–2004	Lab-scale experiments at Kochi University
2004–2009	Bench-scale experiments at Takasu WWTP, Kochi Prefecture, and Noichi WWTP, Konan
2009–2011	Full-scale demonstration at Noichi WWTP, Konan
2011	Operation commencement at Noichi WWTP, Konan
2012	Revision of master plan for sewerage system in Konan
2014	Registered in the JS Innovation Program
2015	Awarded by MLIT
2016	Awarded by JSWE (the JSWE New Technology Award)
2016	Operation commencement at Yasu WWTP, Konan
2018	Operation commencement at Oomi WWTP, Itoigawa
2019	Awarded by JST (Excellent Practice Awards for the STI for SDGs Award)
2020	Operation commencement at Takanosu WWTP, Kita-Akita
2021	Awarded by JSIM
At present	Determination of introduction in nine WWTPs in Japan (As of July 2021)

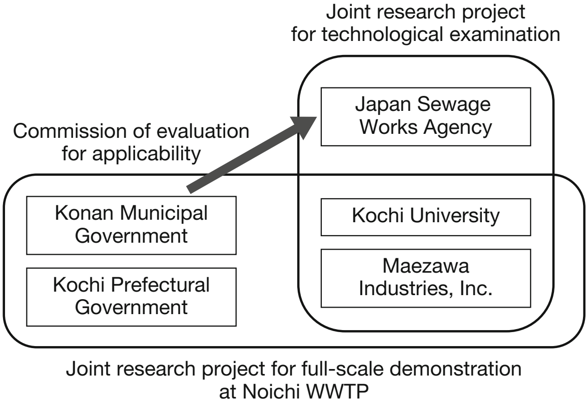

Fig. 11.4 The three-way university–industry–government partnership

an effective parameter for nitrogen removal in the OD process. They also acquired a Japanese patent for a dual DO control system in the OD process, which can automatically control the DO recirculation rate. Detailed information on the DO recirculation rate is available in Sect. 11.2.4.

Thereafter, Kochi University and Maezawa Industries, Inc. jointly launched bench-scale experiments using grid chamber effluent at the Takasu WWTP in Kochi Prefecture in 2004. The core reactor replicated the flow dynamics of typical ODs, and a dual DO control system was installed in the bench-scale plant. The experimental results demonstrated that the dual DO control system achieved considerable nitrogen removal through the stabilization of the ratio between aerobic and anoxic zones, even under the condition of large fluctuation of influent loadings (Chen et al. 2010). Kochi Prefectural Government evaluated the results as successful and introduced the technology to Konan Municipal Government for full-scale demonstrations.

Konan Municipal Government, Kochi Prefectural Government, Kochi University, and Maezawa Industries, Inc. concluded a joint research agreement to construct a full-scale demonstration at Noichi WWTP in 2008. JS, Kochi University, and Maezawa Industries, Inc. also launched a joint research program entitled "Development of energy saving process of wastewater treatment—development of an efficient high-rate OD using dual DO control technology" in 2008 to conduct technological examinations such as project management, conducting a full-scale demonstration, examination of the appropriate design and operational method, and applicability. Konan Municipal Government commissioned JS to evaluate its applicability at Noichi WWTP. The three-way university–industry–government partnership is summarized in Fig. 11.4.

There existed two oxidation ditches at the Noichi WWTP: the first OD (first line) was operated using screw-type aerators, and the second OD (second line) was newly constructed and utilized for a full-scale demonstration of a dual dissolved oxygen control system in the OD process. After conducting clean water tests to evaluate flow dynamics and oxygen transfer in FY 2009, a full-scale demonstration was conducted

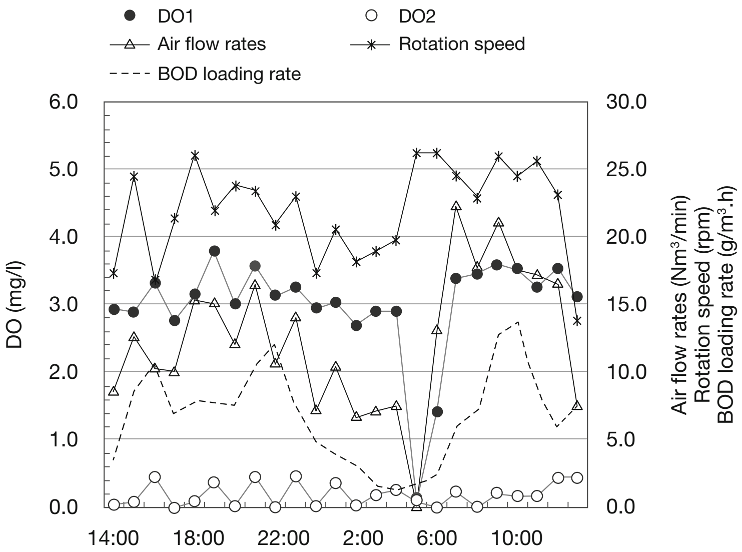

Fig. 11.5 An example of dual DO controls during an intensive survey (February 23–24, 2011). (Reprinted from Fujiwara et al. 2011)

under high loading conditions in FY 2010. All influent sewage to Noichi WWTP was introduced to the second line and water depth was set at 1.5 m. Mean HRT was 16.5 h during the operation in FY 2010 (between May 2010 and March 2011). Detailed information on the operational conditions is available in a previous publication (Nakamachi et al. 2012).

Figure 11.5 presents the profiles of 1-h average DO concentrations, air flow rate of blowers, rotation speed of flow boosters, and BOD volumetric loading rate during an intensive survey between February 23 and 24, 2011. This figure also demonstrates an example of dual DO controls in response to the large fluctuation in influent loading. As shown with the dotted line in Fig. 11.5, BOD volumetric loading rate reached 12.1 g/(m^3 h) at 22:00, then suddenly dropped to a minimum value of 1.29 g/(m^3 h) at 4:00, and finally increased to a maximum value of 13.9 g/(m^3 h) at 10:00. The dual DO controls automatically adjusted the air flow rate and the rotation speed independently to such large fluctuation of influent loading. The values of DO sensor 1 and DO sensor 2 were consequently maintained almost constant. Aeration was stopped by preset timer to adjust extremely low influent loading early in the morning (between 5:00 and 6:00) and only mixing was performed by the flow boosters. Hence, the values of DO sensor 1 and DO sensor 2 at 5:00 became nearly 0 (mg/L) (1-h average between 5:00 and 6:00). Thereafter, the system returned to the dual DO control mode and the DO values also returned to the setpoint immediately. These results clearly demonstrate that dual DO control system is effective for a full-scale OD equipped with blowers, aeration units, and flow boosters.

Figure 11.6 depicts time courses of chemical oxygen demand (COD) and BOD concentration in the effluent. Effluent BOD concentration was 4 ± 3 mg/L

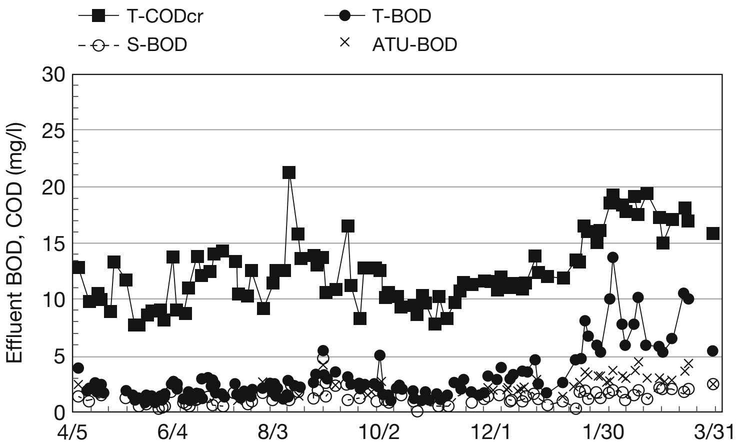

Fig. 11.6 Time courses of effluent BOD and COD concentrations. (Reprinted from Fujiwara et al. 2011)

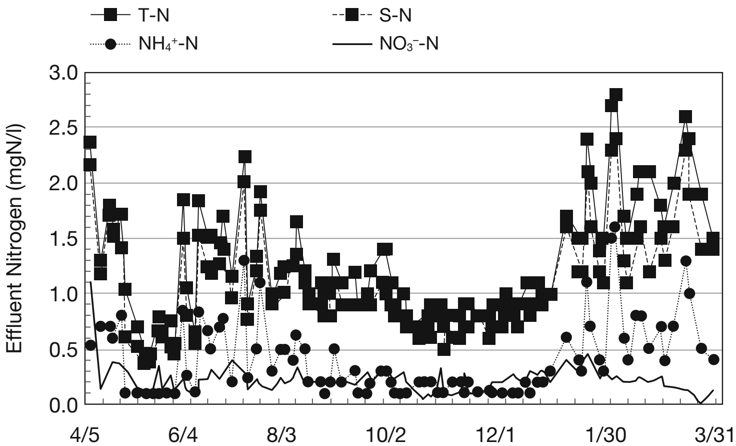

Fig. 11.7 Time courses of effluent nitrogen concentrations. (Reprinted from Fujiwara et al. 2011)

(average ± standard deviation) and 97% of the total BOD was removed on average. Figure 11.7 demonstrates time courses of effluent T-N, soluble nitrogen (S-N), ammonium nitrogen (NH_4^+–N), and nitrate nitrogen (NO_3^-–N) concentrations. Effluent T-N concentration was 1.3 ± 0.5 mg/L, and average T-N removal efficiency was as high as 94% (Fujiwara et al. 2011). These results demonstrated that a dual DO control system realized similar BOD removal and better T-N removal compared to previously reported average values for the OD process (Japan Sewage Works Agency 2000). Figure 11.8 illustrates the relationship between the influent flow rate and unit power consumption for the first line in FY 2009 and the second line in FY 2010. The results demonstrate that the unit power consumption for the

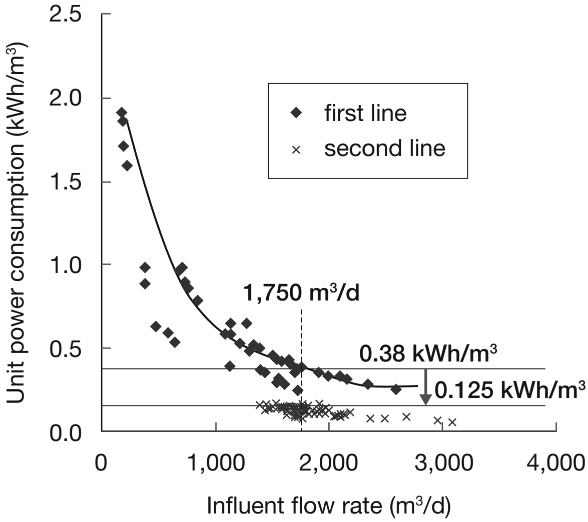

Fig. 11.8 Relationship between influent flow rate and the unit power consumption for the first line in FY 2009 and the second line in FY 2010. (Reprinted from Nakamachi et al. 2012) with the permission of Japan Society on Water Environment)

second line (0.125 kWh/m^3) was only 34% of that for the first line (0.38 kWh/m^3) at the designed influent flow rate of 1750 m^3/day. Rough estimation indicated that the reduction of endogenous respiration by high loading operation, improvement of standard aeration efficiency, and dual DO control contributed to the reduction of unit power consumption by 15%, 28%, and 23%, respectively. The unit energy consumption of 0.125 kWh/m^3 during the full-scale demonstration is much lower than that of a conventional OD process (ca. 0.5 kWh/m^3) and lower than that of a conventional activated sludge system (ca. 0.2 kWh/m^3) in Japan. The drawback of the OD process, high energy consumption, was successfully overcome by introducing the dual DO control system. As shown in Fig. 11.2, unit energy consumption of high-rate trickling filters (TFs) is lower than that of the dual DO control system in the OD process. However, BOD removal rates of trickling filters were inferior to the OD process (low-rate TFs: 80–90%; high-rate TFs: 65–85%) (United States Environmental Protection Agency 2000b), and an additional anoxic process for denitrification is required for T-N removal. As a developing sanitation infrastructure to meet stringent discharge standards, the dual DO control system in the OD process successfully achieved both good effluent water quality and energy efficiency. Additional operation of the second line in FY 2011 under low loading conditions demonstrated that the dual DO control system is effective under both high and low loading operations. Easy maintenance and operation were also confirmed through the full-scale demonstration for 2 years. This advantage will be beneficial for both developing countries and depopulated societies in developed countries to introduce the dual DO control system in the OD process and achieve SDGs.

11.2.4 How Did the Three-Way Partnerships Among University–Industry–Government Overcome Technological Barriers for Innovation?

As mentioned in the introduction, there are several main barriers to the implementation of the circular economy: technological, social, policy and regulatory, managerial, financial and economic, customer, and performance indicators. In this section, the author discusses why the three-way partnerships among university–industry–government were able to overcome technological barriers to implementing a dual DO control system in the OD process.

The first reason is the theoretical analysis of the operational parameters for the OD process. The retention of nitrifying bacteria in the system, appropriate balance of aerobic and anoxic zones, and hydrogen donors for denitrification are extremely important in the process to achieve the simultaneous removal of organics and nitrogen. Of all these conditions, an appropriate balance between the aerobic and anoxic zones is especially difficult to realize because the oxygen utilization rate by activated sludge temporally changes depending on the time variation of influent loading. The author theoretically demonstrated that the DO recirculation rate (R_{DO}) should be adjusted in accordance with changes in the oxygen utilization rate to appropriately manage aerobic/anoxic zone ratio (Fujiwara et al. 2004).

$$R_{\mathrm{DO}} = \mathrm{DO_a}(Q_{\mathrm{R}}/V) \qquad (11.1)$$

where R_{DO} is the DO recirculation rate (g/m^3 h), DO_{a} is the DO concentration at the aeration point, Q_{R} is the recirculation flow rate in the OD (m^3/h), and V is the total volume of the ditch (m^3). The index indicates that both DO concentration at the aeration point and the recirculation flow rate are important factors for achieving an appropriate balance between aerobic and anoxic zones. Based on this analysis, the author conceived the idea of a dual DO control system in the OD process, in which aeration intensity and recirculation flow rate are independently controlled by the DO values at two points. The author and his co-investigators acquired patents for the technology (Tsuno et al. 2009), which was the basis of the three-way university–industry–government partnership.

The second reason is to set the experimental conditions under consideration for scaling up the reactor in the future. The author initially started lab-scale experiments using six completely mixed tanks in series with huge recirculation, which can replicate the typical flow dynamics of ODs. As a result, the experimental results obtained from lab-scale reactors were applicable to bench-scale experiments. Thereafter, the bench-scale reactor was placed in the Takasu WWTP, Kochi, Japan, to treat real wastewater with fluctuations in influent flow rate to replicate actual treatment conditions in future applications. A dual DO control system was also installed in the bench-scale reactor, and the effectiveness of the control system was evaluated. The obtained results were therefore effective for the design and operation of a full-scale plant at the Noichi WWTP.

The third reason is the invention of a new type of DO probe and the introduction of appropriate flow boosters for a dual DO control system. The oxidation ditch process is widely applied in small- and medium-sized communities in Japan, and no operation manager is stationed, and patrol monitoring is carried out; hence, easy maintenance and operation is of great importance. From this viewpoint, DO probes utilizing conventional membrane-electrode methods are not appropriate for such WWTPs because of the requirement of periodical calibration, biofilm attachment on the membrane surface, and the need for sufficient sample flow across the membrane surface. Fortunately, novel optical DO probes, the sensor caps of which should be replaced only around once per year, were developed just before the full-scale demonstration at the Noichi WWTP. This invention made the dual DO control system feasible for ODs in Japan. In addition, Maezawa Industries, Inc. introduced flow boosters with 16 vertical blades for the full-scale demonstration. The vertically uniform shape of the boosters can create an ideal plug flow without shortcuts in the ditch, which makes the dual DO control system stable.

11.3 Social Integration and Acceptance Process of the Technology as an Infrastructure in Depopulating Cities in Japan

11.3.1 Social Integration of the Emerging Technology Contributing to Achieving SDGs in Konan City

In this section, the author summarizes the social integration process of the technology in Konan City and discusses how the following barriers were overcome: (b) social, (c) policy and regulatory, (d) managerial, (e) financial and economic, (f) customer, and (g) performance indicator.

Figure 11.9 summarizes the life cycle of the technology and the various barriers at each phase of the cycle. During the research and development phase, the authors overcame many technological barriers to developing the technology, as mentioned in Sect. 11.2.4. Maezawa Industries, Inc. financially supported fundamental and applied research and installed machinery and electrical facilities for full-scale demonstrations. Therefore, they overcame managerial barriers and achieved performance indicators of the technology during the research and development phase. In addition, permission from Konan City parliament was required to conduct a full-scale demonstration at the Noichi WWTP. All members of the three-way partnerships believed that this technology was sufficiently effective to be disseminated and considered that it would be easily accepted by the parliament members by simply explaining its benefits. However, obtaining their consent was difficult because they were representatives of the citizens and were not technical experts. Therefore, they carefully explained the significance, benefits, and limitations of the technology to the city parliament members elected by the citizens for about half a year. They successfully

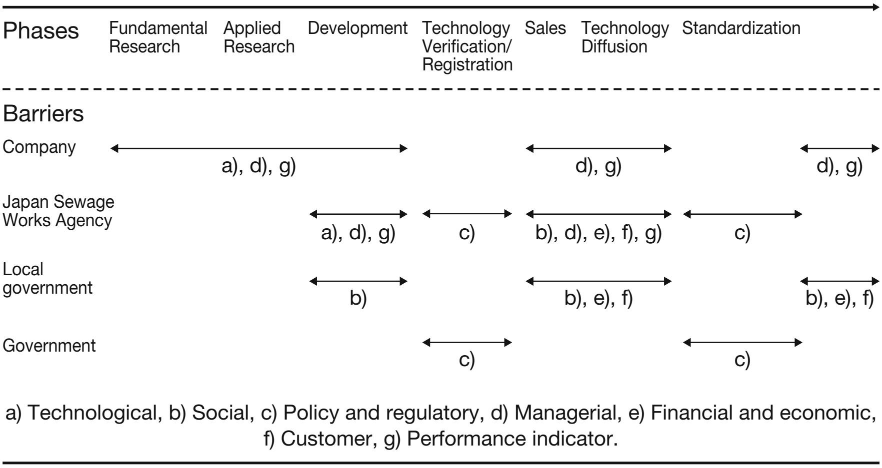

Fig. 11.9 Life cycle of sanitation technology and the various barriers at each phase of the cycle

gained their understanding and were able to start full-scale demonstrations in FY 2009. They thus overcame social barriers to the demonstration.

Sewerage systems were introduced to local municipalities with financial support from the Japanese government. Therefore, the reliability and equity of the employed technology are especially emphasized in Japan as a public service. From this viewpoint, technology verification and/or registration was essential to diffuse new technology after the success of the development. JS has been running the “JS Innovation Program” since 2011, aiming to enhance the development of new wastewater treatment technologies. It also encourages the adoption of registered technologies in contract projects. Kochi Prefectural Government, Konan Municipal Government, Kochi University, and Maezawa Industries, Inc. requested that JS join the three-way partnerships before starting the full-scale demonstration. As mentioned in Sect. 11.2.3, JS accepted the invitation and evaluated its applicability to the Noichi WWTP. JS also registered the new technology in its Innovation Program in 2014, a dual DO control system in the OD process. Konan Municipal Government revised the master plan for the sewerage system in 2012, in which the future integration of 10 WWTPs into two WWTPs is stated for the sustainable management of sewerage systems in future depopulated cities. The developed technology plays a key role in increasing the treatment capacity and realizes the integration of WWTPs in Konan City. Konan Municipal Government continued to utilize the technology at Noichi WWTP after the full-scale demonstration and introduced it to Yasu WWTP after its registration to the JS Innovation Program. They thus overcame policy and regulatory barriers through registration to the JS Innovation Program, and the registration became the basis of sales and technology diffusion thereafter. JST highly evaluated and awarded the three-way partnerships as Excellent Practice Awards for the STI for SDGs Award from the viewpoints of SDGs 6, 7, 11, and 13. This energy-saving sanitation technology directly contributes to both SDGs 6 and 7. Lower unit power consumption of the technology mitigates climate change through reduction of carbon dioxide emission and contributes to SDG 13. Integration of the 10 WWTPs into two WWTPs in Konan City by introducing the technology is expected to save about 400 million JPY, making Konan City inclusive, safe, resilient, and sustainable (SDG 11). Indeed, development and social integration of a dual DO control system in the OD process contribute to achieving SDGs in Konan City.

11.3.2 Contribution of Three-Way Partnerships to the Horizontal Development of the Technology

As of July 2021, nine WWTPs in Japan had introduced a dual DO control system in the OD process. JS designed and constructed facilities introducing the novel system at eight WWTPs based on commissions by local governments. Itoigawa City ordered Maezawa Industries, Inc. to design and construct another facility utilizing the system. Figure 11.10 illustrates the concept of capacity enhancement by introducing a dual DO control system. The influent flow rate of specific WWTPs increases with the dissemination of sewerage systems and the integration of facilities, including other WWTPs and night soil treatment plants. However, it will decrease depending on future depopulation in the area. Considering long-term influent flow rate trends, it is not cost-effective to expand facilities utilizing conventional systems to adopt the peak flow rate because additional facilities will become too excessive during the depopulated phase. Instead, the introduction of a dual DO control system realizes a temporal high-loading operation and enhances the treatment capacity without the

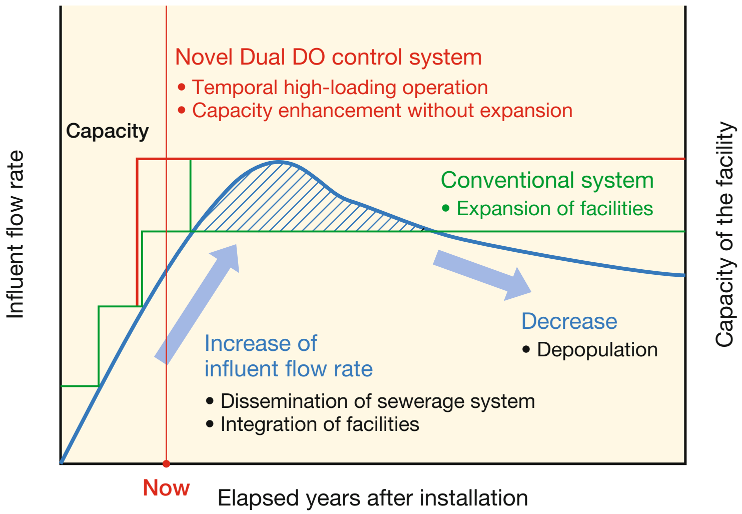

Fig. 11.10 Capacity enhancement through the introduction of dual DO control system

expansion of facilities. Dr. Hashimoto summarized the objectives of installing this system as follows (through multiple responses from each facility): (1) seven WWTPs: avoid expansion of facilities by enhancing the treatment capacity; (2) four WWTPs: increase treatment capacity to integrate other facilities; (3) two WWTPs: increase treatment capacity to receive night soil, etc.; and (4) two WWTPs: reduce installation area and construction cost after process modification to ODs (Hashimoto 2020). In summary, cost reductions due to the enhancement of treatment capacity was the main reason for introducing the system.

Companies generally encounter managerial barriers and performance indicators that must be overcome in the sales and technology diffusion phases, as shown in Fig. 11.9. Maezawa Industries, Inc. and JS are now crossing barriers, and technology diffusion is underway across Japan and globally. The benefits of the dual DO control system mentioned above attract local governments that face social, financial, economic, and customer barriers. Konan Municipal Government welcomes visitors from other local governments and provides them with tours of the Noichi WWTP and Yasu WWTP to explain the system in detail. As mentioned above, the reliability and equity of the employed technology are especially emphasized in Japan as a public service. Therefore, local governments are generally nervous about introducing new technologies into their WWTPs. The frank opinions from Konan Municipal Government could assure them and indirectly support technology diffusion. In addition, Kochi University and Kochi Prefectural Government have annually organized Kochi symposiums on sewerage systems since January 2018, in which various new technologies and initiatives in local governments in Kochi Prefecture have been presented. Many participants from the national government, local governments, and private companies have attended technical tours in the symposium and visited WWTPs employing new technologies, including a dual DO control system in the OD process. Kochi University and Kochi Prefectural Government have indirectly supported technology diffusion by enhancing other local governments' understanding of the system through symposiums.

11.3.3 Stakeholders' Motivations for Joining Three-Way Partnerships

A commemorative round-table talk was held by the *Journal of Sewerage, Monthly* after the reception of the STI for SDGs award. Prof. Taku Fujiwara from Kochi University, Mr. Kenichi Miyata from Konan Municipal Government, Mr. Tsuyoshi Tanaka from Kochi Prefectural Government, Dr. Toshikazu Hashimoto from JS, and Dr. Kazuo Nakamachi from Maezawa Industries, Inc. participated in the round-table discussion; the author served as the moderator. Table 11.2 summarizes the motivations of stakeholders expressed for joining the three-way partnerships (Editorial Department of Journal of Sewerage, Monthly 2020). The member at Kochi University stated that they had been motivated by academic interests, the potential

Table 11.2 Stakeholders' motivations to join the three-way partnerships

	Fundamental research	Applied research	Full-scale demonstration	Technology diffusion
Kochi University	• Academic interests • Publication of research papers • Human resource development	• Academic interests • Publication of research papers • Human resource development • Growth as a researcher	• Academic interests • Publication of research papers • Human resource development • Growth as a researcher • Completion of research and development (R&D)	• Social contribution • Growth as a researcher • Happiness for spread of the developed technology
Maezawa Industries, Inc.		• Growth as an engineer • Publication of research papers	• Growth as an engineer • Publication of research papers • Completion of R&D	• Spread of developed technology to local governments • Spread of developed technology abroad • Deepening of the technology • Contribution to SDGs
Japan Sewage Works Agency (JS)			• JS's history of R&D and standardization and introduction for oxidation ditch (OD) process • Requirement to enhance treatment capacity of OD process • R&D for reconstruction and renewal of existing ODs	• Request for introduction of the developed technology from local governments (integration of WWTPs, temporal increase of influent flow rate, etc.) • Energy saving of OD process • Future standardization
Kochi Prefectural Government		• Desire for inexpensive and high-quality wastewater treatment system • Dissemination of sewerage system in Kochi Prefecture	• Dissemination of sewerage system in Kochi Prefecture • Realization of sustainable sewage works	• Reconstruction and renewal of existing ODs in Kochi Prefecture • Integration of sewerage system and rural sewerage facilities

(continued)

Table 11.2 (continued)

	Fundamental research	Applied research	Full-scale demonstration	Technology diffusion
Konan Municipal Government			• Enhancement of treatment capacity • Cost reduction	• Enhancement of treatment capacity • Reduction of cost and electric consumption • Easy maintenance • Integration of WWTPs • Expansion of sewerage area

publication of research papers, and human resource development throughout the project. As the main tasks of academia are education and research, these members' motivations are natural. Interestingly, their motivations expanded to growing as researchers and feeling happy about the spread of the developed technology during the phases of applied research, full-scale demonstration, and technology diffusion. Discussions in the three-way partnership broadened their minds and visions and increased their motivations. The members from Maezawa Industries, Inc. joined the project from an applied research perspective. Their main motivations were growth as an engineer, completion of R&D, and the spread of developed technology. As members of a private company, their motivations for the completion of R&D, sales, and spread of developed technology are essential, and Dr. Nakamachi was satisfied with the project because of his growth as an engineer. In addition, winning the Excellent Practice Awards for the STI for SDGs Award highly motivated them from the viewpoint of their contributions to the SDGs. The motivations of JS were based on the history and recent situations of the OD process. JS has enabled the research and development, standardization, and introduction to most local governments of the OD process. The deadline of reconstruction and renewal of existing ODs is approaching for many WWTPs, and innovative technologies that can enhance the treatment capacity of OD processes are now required by local governments for various reasons such as integration of WWTPs, temporal increase of influent flow rate, and energy saving, among others. JS is now considering the future standardization of the "dual DO control system in oxidation ditch process" and its further diffusion. Kochi Prefectural Government desired an inexpensive and high-quality wastewater treatment system for the dissemination of its sewerage systems. They strongly supported conducting full-scale demonstrations at Noichi WWTP in Konan City and indirectly supported technology diffusion after the development by organizing the Kochi symposium on the sewerage system. The motivations of Konan Municipal Government were the enhancement of treatment capacity and cost reduction. The developed system is effectively utilized both at Noichi WWTP and Yasu WWTP, and the enhancement of treatment capacity, reduction of cost and electric consumption, and easy maintenance are realized. Future integration of WWTPs and expansion of sewerage areas is expected based on the revision of the master plan for the sewerage system in Konan City in 2012.

11.4 Summary

In this chapter, the author examined the history of the R&D and technology diffusion of the "dual DO control system in oxidation ditch process" and discussed the social integration and acceptance of emerging sanitation infrastructure. Three-way university–industry–government partnerships supported the completion of the project in a satisfactory manner. The following elements made the project successful:

1. Enthusiasm of all stakeholders toward the shared goal of the project.
2. Win-win relationships among stakeholders based on their motivations and respect for each other.
3. Research and development considering future applications and technology diffusion.
4. Participation of local governments in the joint project as important stakeholders.
5. Agreement of the municipal parliament of Konan City based on a careful explanation of the significance, benefits, and limitations of the system.
6. Registration of the "JS Innovation Program," which encourages the adoption of registered technologies in JS's contract projects.

The sustainable management of sanitation systems is essential for protecting the health of individuals and drinking water sources in both developing countries and future depopulated societies in developed countries. The author hopes that the information provided here will be useful for realizing sustainable sanitation systems through the introduction of innovative technologies.

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