General introduction

Over the past 50 years, the layout of the Parisian sanitation system has radically changed, shaped through three major milestones. Beginning in the early 1970s and over a 10-year period, a major industrial revolution led to a strong treatment capacity expansion at the Seine-Aval wastewater treatment plant, which would become one of the largest plants worldwide. This first step was followed by an another crucial 10-year phase, from 1980 to 1990, which focused not only on building new plants to bring on-line a significant increase in treatment capacity but also, and based on an intensive applied research activity, on preparing for the treatment plant changes required in response to environmental expectations. Lastly, the changes occurring during the past 25-plus years, from 1990 to present day, have been aimed at improving water treatment quality from removing only carbon to the complete removal of carbon, nitrogen and phosphorus (Rocher & Azimi, 2017). Such industrial changes have significantly contributed to decreasing pollutant discharges into the Seine River while restoring its physiochemical quality. Consequently, the oxygen level in the river is now quite good, and the nitrogen and phosphorus concentrations are much lower than in past years. These conditions favor the resurgence of numerous fish species, with a recent record of 32 (whereas only three were counted in 1970) (Rocher & Azimi, 2016).

The Parisian sanitation system now faces new challenges in managing the wastewater produced by nine million inhabitants in a densely urbanized area. More efficient use and management of wastewater are critical to addressing the growing demand for water and the threats to water security. In this context, the

Case of Chemical Disinfection Using Performic Acid
Editors: Vincent Rocher and Sam Azimi
doi: 10.2166/9781789062106_xxi

evolution of social expectations in favor of wastewater reuse and the City of Paris' pledge to open the Seine River to Olympic and Paralympic swimmers, as well as to all Parisians, in 2024 have brought the issue of bacterial pollution to the forefront (Directive 2006/7/CE, 2006). This issue seeks to identify and quantify the main input pathways of bacteria into the river (treatment plants, storm overflows, etc.) in order to define the best action plan for achieving the recreational use objectives. Various solutions have been devised on the scale of the Paris Metropolitan Area, and scenarios have been tested using the PROSE mathematical model to establish and prioritize the actions to be carried out. PROSE is a modeling tool, calibrated and validated on the Seine River, intended to simulate nutrients and bacterial contamination within the Parisian watershed; moreover, since 2007, it has been used by the Greater Paris Sanitation Authority (SIAAP) to design the Greater Paris sanitation master plan.

For all scenarios examined, disinfection of the effluent conveyed by the wastewater treatment plants located upstream of the City of Paris appears to be a necessary action. Indeed, bacterial contamination of the Seine River has been shown to be significantly higher downstream of the wastewater treatment plant outfalls (Figure 1).

During dry weather conditions, wastewater treatment plants significantly contribute to bacterial concentrations in the river. The median concentration discharged into the river has ranged from 5×10^3 to 50×10^3 MPN/100 mL of *Escherichia coli* (*E. coli*) (Rocher & Azimi, 2016), leading to a median concentration level in the river of 1200 MPN/100 mL at the Port à l'Anglais site, located downstream of the outfall. Thus, to be compliant with the bathing quality objectives, the disinfection of the outfall becomes crucial to limit the bacterial concentrations in the river. The situation is quite different during rain events. Relying mostly on a combined sewer system, the Greater Paris Sanitation Authority operates more than 400 km of pipes to handle wastewater for treatment into six plants. While during dry weather periods the facilities are able to treat the entire flow, such is not always the case during wet weather periods. During rain events, due to the high level of impermeable surfaces, additional rainwater significantly increases the flow rate into sewer pipes and exceeds the drainage and treatment capacities of the whole sewer system, thus inducing combined sewer overflows (CSOs) into the river. This untreated CSO discharges water, containing up to 5.5×10^6 MPN/100 mL of *E. coli*, into the river (Rocher & Azimi, 2016). In this case, CSOs become the main introduction pathway of *E. coli* into the Seine River (Figure 1, yellow curve, occurring during the rain event after 28 hours of simulation) and the disinfection of the plant outfall, which was of prime importance during dry periods, appears useless for the river to be compliant with bathing quality objectives

While the main objectives for the years ahead concern the ability to manage rainwater in compliance with the water framework directive (WFD, 2006), tackling the bacterial contamination due to wastewater during dry periods becomes of critical importance in significantly reducing the Seine River contamination level. Though Rocher and Azimi (2016) have shown that conventional wastewater treatment facilities offer a satisfactory bacteria removal rate (ranging from 2.76 to 3.03 log for *E. coli* and 2.73 to 3.37 log for intestinal enterococcus), it would appear that additional treatment processes are still required in order to significantly reduce the bacterial contamination of WWTP outfalls.

To help stakeholders in their choice for any additional treatment, the SIAAP has integrated into its scientific program, through its Mocopée research program, an action to study the disinfection processes and their effectiveness and harmlessness to the environment.

Among the technologies currently available for disinfecting wastewater outfalls, chemical disinfection appears to be a well-adapted solution due to both its operational flexibility and efficacy at removing bacterial contamination. While several chemicals are known to disinfect water, performic acid (PFA) is currently being used by some municipalities (Biarritz, France and Venice, Italy). This is the basis for SIAAP's testing of PFA to disinfect its Seine Valenton wastewater treatment plant outfall. A two-year study was performed both in the laboratory and at full-scale. This provided answers regarding both the efficacy and the absence of environmental impact of this disinfection process. This book sets out and discusses the expected outcomes of using PFA under three headings:

- Assessment of the efficacy of this type of chemical disinfection on WWTP outfall;
- Technical feasibility of full-scale implementation;
- Verification of the minimal impact on the River Seine.

A fourth section, which reports feedback from the municipalities where PFA disinfection has already been implemented, serves to complete this overview.