

# Effectiveness of Disinfecting Wastewater Treatment Plant Discharges: Case of Chemical Disinfection Using Performic Acid

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**SIAAP**  
Service public de l'assainissement francilien



# Effectiveness of Disinfecting Wastewater Treatment Plant Discharges: Case of Chemical Disinfection Using Performic Acid

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**Edited by**

**Vincent Rocher and Sam Azimi**



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# Preface

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Writing a book is not an easy task, as anyone who has ever written one knows. Besides the content, there are many questions to ask before successfully telling the story ... A book to say what? For whom? In what form? And once you have all the answers to these questions, there is one last question that remains elusive: How do you tell the story? Raymond Queneau illustrates this difficulty very well by telling us in 99 different ways the simple story of a man traveling in a bus (*Exercices de style*, Raymond Queneau. 1947).

Regarding the subject of access to water, its use, and more particularly, on the subject of bathing in urban areas, the choice and the way of telling the story are even more complicated. There are not 99 but thousands of ways to approach the subject, thousands of ways to tell this story of primary interest to each of us. Each of these ways will be fair, each of these ways will answer many questions and fuel reflections ... But each of these ways will also leave out a number of questions. To choose means to exclude.

As a public authority in charge of wastewater treatment, our role has been to tell the story of disinfection from a technical perspective. A technology has been chosen and tested, from laboratory scale to full-scale trials... From an idea to its industrial feasibility. We tried to answer all the questions that came to a stakeholder's mind, with an operator and an end-user eye. No bias on the results. No position taken on the technology. The objective of our story has been to give, in a factual way,

## **x**      Disinfection of WWTP Discharges using Performic Acid

the results of the tests, starting from the development of the protocols, passing through the evaluation of technology's effectiveness and the verification of its harmlessness on the environment. Thus, the reader can, at will, read all or a part of the book according to his own questions, expectations, and objectives ... To tell his own story!

In order to be able to address all of these subjects, to answer all of these questions, we have put all the required skills around the table, ending up all together with 23 co-authors. This method of doing things is limitlessly rich since collective competence is much greater than the sum of individual skills and that's why all co-authors are named at the beginning of the book regardless to their specific contribution to each chapter. Only the fourth part includes the name of the contributors at the beginning of each chapter since these works have been added to the book to complete the overview.

We hope that you will have as much pleasure in reading this book as we have had in writing it...

Happy reading!

**Vincent Rocher and Sam Azimi**

# Contributors

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## The editors

**Vincent Rocher** heads up Innovation at the Greater Paris Sanitation Authority (SIAAP). After completing his environmental studies with a thesis on the fate of micropollutants in the sewer system, he entered SIAAP to work as a member of the technical and scientific support team. As Director of Innovation, Vincent now works on defining and implementing SIAAP research and innovation policy, in overseeing: asset management aspects, operational control and optimization of the entire sanitation system, and preparation of technical specifications and future regulatory requirements. Leader of the scientific research program, he provides support to the Executive Board and all SIAAP operational departments on technical and scientific matters.

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*Sam Azimi and Vincent Rocher*

The editors would like to thank the co-authors, the editorial supervisor and other contributors of this book, details of whom are given below.

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**Sébastien Pichon** is a research technician in charge of the technical platform dedicated to process engineering studies at SIAAP's Innovation Division. He earned a D.U.T. professional degree in Biological Engineering (Lille University of Sciences and Technologies) in 1999 and prior to his current experience, Sébastien has conducted various studies in the field of wastewater treatment spanning the laboratory, pilot and industrial scales. He had also worked on developing a microbiology laboratory specialized in wastewater treatment and moreover conducted environmental and health studies related to the microbiological quality of water in cooling circuits.

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He then spent nearly 15 years supervising the building of wastewater treatment plants for SIAAP. Since 2016, Jérôme has held the post of Deputy Director and then Director for the three SIAAP wastewater treatment plants located in the eastern part of the Greater Paris area, upstream along the Seine River. This unique geographic configuration makes these WWTP plants critical to hosting open water events at the Paris 2024 Olympic Games.

### **PARIS-EST CRETEIL UNIVERSITY**

**Gilles Varrault** is a Professor of chemistry at the Laboratoire Eau, Environnement et Systèmes Urbains (LEESU) at the University of Paris Est Créteil. He obtained his PhD in the field of environmental sciences from the University of Paris VII in 2001. He was appointed to the post of Assistant Professor at the University in 2002 and received tenure in 2013. Until 2014, his research activities had mainly pertained to metal and organic pollutants in aquatic systems, with special attention focused on their bioavailability. Since 2014, Gilles has also worked on characterizing organic matter in receiving environments as well as in wastewater treatment plants through the use of spectrometric techniques. Furthermore, he helps develop sensors for the high-frequency, *in situ* monitoring of organic matter.

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## **The editorial supervising**

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## The contributors

In addition to the co-authors there are a number of contributors to this book who have provided significant assistance, in particular for the full scale trials detailed in part 2.

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# General introduction

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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

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  $5 \times 10^3$  to  $50 \times 10^3$  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  $5.5 \times 10^6$  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.