

# Developing new uses for wastewater

## THE FUTURE OF SANITATION P. 3

- *Optimizing existing systems and processes*
- *Staying ahead of new trends*
- *Managing impacts on human health and the environment*

## INDUSTRIAL EFFLUENTS P. 7

- *Expanding the range of services to industry through sustainable treatment solutions*



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Printed on paper using 40% ECF fiber sourced from sustainably managed forests and 60% recycled paper.

**T**he field of municipal and industrial wastewater treatment is on the threshold of a transformation. Treatment standards are increasingly stringent to prevent risks to human health and the environment, particularly in terms of emerging pollutants and greenhouse gas emissions. Moreover, in an era when 40% of the world's population has no access to even basic sanitation, there is a need to develop systems and processes designed to allow the most widespread access possible. Finally, wastewater remediation has a role to play in alleviating the pressure on natural resources by recovering and producing energy, reclaiming municipal and industrial effluents for reuse, and deriving secondary raw materials from the recoverable components of wastewater.

These are the goals that researchers are pursuing at Veolia Environnement: for example, they are improving processes and existing systems to achieve energy savings or lower capital costs; they are finding ways to differentiate Veolia Environnement from its competitors; they are developing innovative systems to make wastewater treatment plants energy self-sufficient, reclaim treated wastewater, produce biopolymers and recover solvents and metals.

They are also striving to better control atmospheric emissions, develop tools to identify emerging pollutants at the source and characterize pollutant streams.



*With a mere 10% of the world's cities today equipped with wastewater treatment infrastructure, solutions for wastewater remediation and reclamation are among the major global challenges that must be addressed to avoid contaminating the public or jeopardizing ecological balances, and to meet humanity's demand for freshwater. The need for viable solutions that can be deployed on a massive scale is especially urgent in light of the projected doubling –to four billion–of the urban population in developing countries by 2030. This growth will go hand in hand with an increase in the volume of wastewater and the demand for drinking water.*



*The varied nature of industrial effluents calls for tailor-made treatment processes that meet criteria for efficiency and reliability conforming to regulatory requirements for effluent discharge and safety. In addition, recycling must be developed to limit the quantity of final waste and conserve natural resources.*

## THE FUTURE OF SANITATION



### CHALLENGES

#### SHORT-TERM ENHANCEMENTS TO THE EFFICIENCY OF EXISTING SANITATION PROCESSES AND SYSTEMS

- **Optimizing the efficiency and cost of biological treatment processes.**  
The use of microbes to purify wastewater through natural processes is a longstanding practice and a core solution for wastewater remediation. However, to conserve water resources and minimize the environmental impacts of discharge, we must optimize the sizing and management of our processes.
- **Developing end-to-end solutions for managing sanitation systems in order to better protect the natural environment and conserve freshwater resources.**

Decisions regarding sanitation policy and infrastructure must reflect all the components of the municipal collection and treatment system: namely, sewage and storm drainage networks, wastewater and sludge treatment processes, and compact sanitation plants. Appropriate methodologies and tools must be developed to integrate these separate components into a coherent whole that will pave the way to improved management especially during rainy weather. Reinforcing the link between the wastewater and sludge chains will provide a comprehensive vision of technical performance levels and costs.

#### Schedule

- New routes for wastewater remediation and reclamation: 2006-2020
- Modeling of biological treatment units: 2004-2012
- Biological process control: 2005-2009
- Molecular and functional characterization of microorganisms: 2005-2015
- Evaluation of individual wastewater systems: 2005-2011
- Study of emerging micropollutants: 2005-2013
- Optimization of sludge digestion processes: 2005-2011
- Integration of drying: 2007-2009
- Athos™: 1993-2010
- Optimization of materials and energy consumption: 2007-2020

## Summary

#### R&I AIMS:

- Optimize the efficiency and cost of biological treatment processes and develop end-to-end wastewater management solutions that afford the best conservation of the receiving environment and freshwater resources.
- Design the sanitation system of the future based on the systematic recovery and reuse of all components of wastewater and sludge: reclaimed water, organic matter that can be converted into bioenergy and biomaterials, minerals that can be incorporated into fertilizers.
- Plan risk management strategies to address foreseeable environmental and sanitation challenges.

#### AVENUES OF RESEARCH:

- Improving our knowledge of processes.
- Developing advanced tools of investigation.
- Capitalizing on new contributions from biotechnology and microbiology.
- Integrating new modeling and control tools.

#### RECENT DEVELOPMENT HIGHLIGHTS:

- Production of biopolymers in compliance with the specifications of a bioplastics manufacturer.
- Abatement of atmospheric emissions, especially odor-causing compounds and greenhouse gases.
- A low-energy process for nitrogen removal.
- Construction start on a platform dedicated to testing new sanitation processes.

• **Controlling the quantity, quality and processing of sludge**

Generating energy from wastewater or treatment plant sludge is already being achieved via anaerobic digestion. When added to other measures such as energy savings, production of renewable energies and energy recovery, this action will give wastewater management a positive energy balance. Furthermore, better control of the substances that enter sanitation systems should help lower the concentrations of certain toxic compounds in sludge.



The two wastewater treatment plants for the Milwaukee metropolitan area (United States) serve a population of 1.1 million.

**PREPARING FOR THE BIG SHIFT IN THE SANITATION SECTOR**

By 2020-2025, wastewater treatment plants will have become biorefineries. They will implement new biological treatment processes that are more intensive and more targeted to allow not only wastewater remediation but also value-added recovery as reclaimed wastewater, bioenergy and biomaterials. This will be achieved by bringing biotechnology, microbiology, process engineering and applied mathematics into play.

**A patent for an ultra-compact reactor for odor-removal**

In conventional wastewater treatment, odor removal is carried out in chemical scrubbing towers which often stand several meters tall and have a large surface footprint. Veolia Environnement has filed a patent for a technique that reduces the size of these installations by a factor of three or four.

**BETTER MANAGEMENT OF ENVIRONMENTAL AND HEALTH RISKS**

- To enable us to be ready to adapt our customer's facilities to foreseeable regulatory changes, and make them even more efficient, we need to carry out a qualitative and quantitative assessment of the environmental and health impacts of wastewater treatment operations, particularly in terms of emerging micropollutants and the carbon and water footprints of the processes.
- Solutions are needed to isolate and treat the refractory pollutants found in wastewater treatment plant sludge.

**Athos™ :**  
a mineralization process for wastewater treatment sludge

Athos™ is a commercial mineralization process involving the wet oxidation (as an alternative to combustion) of wastewater sludge. This process generates three byproducts that can be reclaimed or discharged to the environment without any negative impacts (a clean gas, a biodegradable organic liquid and an essentially mineral solid residue).



**Biological treatment:** Today's biological treatment processes entail the use of microorganisms able to transform massive quantities of the organic and inorganic compounds contained in wastewater. Most activated sludge processes involve flocculating microorganisms cultivated in reactors, which are coupled to clarification or membrane filtration units. In biofilm processes, the microbes are cultivated on fixed media (fixed film biofilters) or mobile media (fluidized bed bioreactors). Pollutants intimately mixed with the water are captured and utilized by billions of microorganisms, which then can be separated easily from the treated water.

**PROJECT DETAILS**

**EXISTING SANITATION SYSTEMS**

- **Optimization of biological treatment processes**
  - Higher throughput and removal efficiency of anaerobic sludge treatment processes to produce methane-rich biogas.
  - Better control of the biological activity of the purifying microorganisms through improvements in reactor design and biofilm materials.
  - Development of larger, more reliable membrane bioreactors.
- **Development of decision-support tools**
  - Monitoring and control systems for managing wastewater treatment processes; development of new processes; integrated management of infrastructure (sewage systems + treatment plants).
  - Development of mathematical diagnostic and predictive tools (models, simulations) for treatment plants, to improve the design of new plants and facilitate operations and trouble-shooting on existing plants.
- **Optimization of sludge treatment processes**
  - Improvement in sludge destruction systems (mineralization): wet oxidation, combined treatments (thermal + biological).
  - Study of health and environmental impacts and life-cycle analyses of the various available sludge management processes.
  - Selection and sizing of drying technologies (solar, thermal) appropriate for the various sludge treatment chains.

**TOMORROW'S SANITATION SYSTEMS**

- **Characterization of the resources available from wastewater.** Identification of all biochemical families (proteins, sugars, fats, fibers, etc.) in order to find outlets for them in green chemistry.
- **Development of industrial microbiology (biorefinery)**
  - Selection of tools from the biotechnology and microbiology fields for adaptation to wastewater treatment. Transfer of technologies used on an industrial scale in other sectors (agrifoods, flavorings, pharmaceuticals and personal care products)
  - Identification of microorganism classes in nature that have the capacity for more intensive activity, biodegradation of new pollutants, or accumulation of molecules with potential applications in green chemistry.
  - Development of culture methods and reactors designed to put these new combinations of microbes to work on an industrial scale.
  - Development of methods for analyzing microbial populations and activity to achieve better process control.
- **Energy production**
  - Development of new processes for methane production from wastewater or sludge via new metabolic pathways, in order to optimize the production of biogas available for waste-to-energy, heat production or biofuels applications.
  - Energy self-sufficiency of wastewater treatment plants and wastewater biorefineries.
  - Identification and sizing of new energy production processes.

• **Production of organic ingredients**

Extraction of secondary raw materials from wastewater or treatment sludge to be reclaimed directly or indirectly in green chemistry (the organic matter in wastewater is a source of green carbon).

• **Minerals recovery**

Investigation of new ways to return minerals to the soil: extraction of various constituents from wastewater or treatment sludge for use in fertilizers (phosphorus, nitrogen, sulfur).

• **Wastewater reclamation**

- Establishment of specifications for the various applications for reclaimed wastewater, i.e.; flushing systems, irrigation, drinking water.
- Development of innovative solutions and applications for reclaimed wastewater.



In Queensland (Australia), the Western Corridor Recycled Water project recycles wastewater to supply purified water to two power plants.

**IMPACTS ON HEALTH AND THE ENVIRONMENT**

- **Emissions abatement**
  - Characterization and management of atmospheric emissions including greenhouse gases.
  - Treatment of atmospheric emissions, particularly odors (ultra-compact process), volatile organic compounds, bioaerosols and microparticles.
- **Determination of the fate of emerging pollutants** (endocrine disruptor compounds, pharmaceuticals, priority chemical substances) in various treatment plant configurations and receiving environments.
- **Development of methods for analyzing** these pollutants in all wastewater matrices.



A pilot bioreactor used to produce biopolymers.



Plants selected for their root system provide habitat for microbes that degrade the contaminants in wastewater.



Research is exploring the methane-production potential of wastewater.



A pilot biogas plant at the Cergy wastewater treatment plant (France).

## Interview



Emmanuel Trouvé,  
Wastewater Research  
Program Manager

**“Fifteen years from now, wastewater treatment plants will have evolved into a recycling plant to process all the resources that wastewater contains.”**

### How do you see the wastewater treatment plant of the future?

« Today, the main purpose of a wastewater treatment plant is to treat wastewater so it can be reclaimed as clean water. That process not only consumes a great deal of energy and chemicals, it also generates a substantial quantity of byproducts, including biosolids (sludge). The latter amounts to between 55 and 60% of the incoming organic matter. We are focusing our efforts on optimizing existing processes, decreasing energy consumption, reducing atmospheric emissions and limiting sludge production.

Yet these improvements fall short of the mark in terms of sustainability. The shift now under way reflects a change in perspective. Rather than viewing wastewater as a stream of water laden with pollutants, let's consider it as a resource! Indeed, it contains a large quantity of organic and mineral compounds which, taken individually, can be of value. Our intention is to separate these compounds and maximize their value by using them as energy and other useful materials. »

### Will the “water” component of wastewater be recycled as well?

« The primary goal of wastewater collection and treatment is to discharge treated water that will not have any impact on the environment, thereby helping to sustain the water cycle and keep the quality of water resources intact, unaltered by human activity. Increasingly though, some regions of the world are confronted with ‘water stress,’ due to urbanization and imbalances between water needs and available resources. This stress is often aggravated by climate phenomena. In this context, the reclamation of treated wastewater must be part of an overall plan for matching needs to available quantities. To this end, we are developing solutions for these situations that will allow

treated wastewater to be reclaimed directly for specific applications (irrigation, industry, etc.) to conserve natural resources, or indirectly in the form of aquifer recharge and reservoirs to maintain available volumes regardless of the situation. »

### You also mentioned energy production.

« The carbon content of wastewater sludge can be converted to methane, which in turn can be used to fuel electric turbines or vehicles. The aim is to achieve energy self-sufficiency in wastewater treatment plants. Already, the plants at Achères (France) and Budapest (Hungary) meet 60% and 75% of their energy needs, respectively, via the anaerobic digestion of their sludge. This is a clear example of bioenergy, since the fuel gas is being produced from the biomass derived from the biological purification of wastewater. »

### How will you go about producing other materials of interest to industry?

« Our goal is to produce biomaterials that conform to industry standards. These biomaterials can be used in place of those made from hydrocarbons. In fact, we can even make such substitutions within our own biological treatment processes in some cases.

For example, when the microorganisms used to degrade organics in wastewater are cultivated in a certain way then subjected to stress, they stock reserves of biopolymers, which are similar to the petroleum-based compounds produced in the petrochemicals industry. The only difference is that this is ‘green’ carbon. Already in 2009, we manufactured biopolymer beads according to specifications issued by a bioplastics manufacturer. Sludge can also be used to produce ingredients that can be incorporated into a manufacturing process. For example, the phosphorus, nitrogen and sulfur contained in sludge each can be isolated, removed and delivered to the fertilizer industry. »

### Where is the sanitation field headed?

« By 2020-2025, wastewater treatment plants will have evolved into biorefineries—industrial production facilities that use the tools of biochemistry, biotechnology and microbiology. We have already begun to build an R&I platform to test a variety of innovative sanitation solutions. The Environment is an industrial challenge: the work we are doing today will enable Veolia Environnement to meet that challenge by developing sustainable, integrated value chains for the production of bioenergy and biomaterials. »

## INDUSTRIAL EFFLUENTS



## CHALLENGES

Industry strives to manage its effluents under the best possible environmental and economic conditions. Technology innovations can go a long way towards achieving this goal. To help companies curb their pollutant emissions affordably and better manage their industrial risks, we must expand the range of services offered by Veolia Environnement and tailor our solutions to each industrial sector and context.

### BETTER CHARACTERIZATION OF WASTE

Greater familiarity with the nature of industrial wastes is a factor in choosing and designing the best treatment lines more quickly. To gain this knowledge, we are focusing our efforts on characterizing the pollutant loading by means of quick, online methods (implemented in situ at the heart of the process). In addition, more detailed analytic methods are applied to characterize effluents of low biodegradability (i.e., identification of the various pollutant fractions).

### OPTIMIZING TREATMENT PROCESSES

Our aim is to enhance and secure the technical and economic performance of our processes, specifically by boosting removal efficiency, decreasing energy consumption, enhancing process reliability, ensuring long-term efficiency and operational safety. This means:

- exploring the possibilities of the various available technologies (physical-chemical, thermal, biological and membrane processes) and gaining a better understanding of the phenomena involved;
- developing differentiating and innovative solutions;
- improving the treatment of complex industrial effluents like the high-saline effluents generated in several industrial sectors. In this area, landfill leachates offer a valuable matrix for study; they can be used to test various treatment technologies and take advantage of their potential complementarities within the framework of an end-to-end process.

### MAXIMIZING THE VALUE OF INDUSTRIAL EFFLUENTS

We must seek to extract as much value as possible from certain components of the industrial waste stream as part of a comprehensive treatment process that encompasses not only separation, removal, neutralization and stabilization steps but also the recovery and reuse of the byproducts these treatment steps will generate.

## Summary

Drawing on our broad-based wastewater treatment expertise (in thermal, physical-chemical, biological and membrane processes), our R&I projects aim to expand the range of services that Veolia Environnement provides to industrial customers, and to contribute to developing sustainable treatment solutions for industrial wastes. The scope of our research extends to all industrial sectors.

### MAJOR DEVELOPMENT HIGHLIGHTS:

- Decision-support tools based on effluent characterization. Examples: a tool for online analysis of effluent variability that alerts the operator to any unusual characteristics of treatment plant influent at the head of the line; an online operational support tool for paint booth effluent treatment.
- Evaluation of treatment processes for complex effluents, such as high-saline effluents.
- Development of a catalogue of technology solutions to guide the choice of mineral precipitation processes.
- Development of physical-chemical processes for selective recovery of solvents and metals in solid matrices such as batteries and catalysts.
- Modeling and process control tools.

## Schedule

- Test platform for high-saline effluents\* treatment processes: 2005–2010
- Effluent variability analysis tool: 2005–2009
- Treatment of piggery effluents: 2005–2009
- Study of advanced anaerobic processes: 2005–2011
- Mineral precipitation: 2006–2009
- Electrochemical processes: 2006–2010
- Treatment of surface treatment effluents: 2006–2009
- Selective solvent extraction of metals: 2005–2010

\*notably leachates

## PROJECT DETAILS

### POLLUTANT CHARACTERIZATION TOOLS

- Studies of effluents from chemical plants, steel mills and paper mills serve as a basis for defining tools to characterize pollutant flows (fractionation of the pollutant load, development of acceptability tests in wastewater treatment plants, new analytical protocols, etc.).
- Development of a tool for online analyses of industrial effluent variability using the UV spectrum of the effluents.



■ Petroleum effluents—BP's Lavera Refinery

### COMPLEX INDUSTRIAL EFFLUENTS

- Technical and economic analysis of the various treatment pathways for high-saline industrial effluents, based on pilot studies conducted on an experimental platform.
- More reliable process control in paint booth effluent treatment to detect potential anomalies.
- Optimization of effluent treatment processes for the surface treatment sector as part of the LIFE ZP (Zeroplus) project, which targets “zero liquid discharge” (50% co-financed by the EU).

### PROCESSES FOR DIFFERENTIATION AND INNOVATION

- Development of hybrid biological processes such as the MBBR (Moving Bed Biofilm Reactor): application to effluents from the agrifoods, papermaking and petrochemicals industries and to high-saline effluents.
- Evaluation of mineral precipitation processes for the chemicals and/or mining industries.
- Development of a new-generation heat exchanger.

### TREATMENT OF LIQUID PIG MANURE

LIFE Environment” Zero Nuisance Piggeries Project co-financed by the European Union (30%). Treatment of fresh liquid manure from piggeries and a proposal for a treatment line providing a comprehensive system to manage odor problems relating to hog farms, particularly through the use of reclaimed wastewater to rinse down the facilities.

## The diversity of industrial effluents

Production and manufacturing activities generate wastes that may be liquid (in which case they are termed “industrial effluents”), semi-liquid or solid. Produced in small quantities or substantial flows, each type of waste is unique in the broad range of pollutants it can contain (hydrocarbons, organic compounds, metals, salts, etc.) at highly variable concentrations. These characteristics determine the hazard classification of the waste.



## METALS RECOVERY

Industrial effluents, urban wastewater and many types of hazardous waste contain metals.

To conserve natural resources, avoid disseminating metal pollutants into the environment and minimize the related health hazards, it is essential to develop technologies for concentrating and recovering these pollutants dependably and under environmentally safe and economically viable conditions. R&I efforts are therefore focusing on developing innovative recycling processes such as physical-chemical selective separation processes to reclaim metals as secondary raw materials.

### SOLVENT AND METALS RECYCLING

- Extraction of metals from liquid effluents for recovery/reuse.
- Study of liquid-liquid extraction (a physical recovery process to recover or purify compounds based on their relative solubilities in different immiscible liquids).

### MODELING AND OPERATIONAL ASSISTANCE

Development of operational support tools (decision-support and tools for advanced process control) and modeling tools for physical-chemical, biological and thermal processes in order to enhance the reliability and operational safety of our processes.



## Interview



Jean Cantet,  
Director, Process  
Engineering Department

**“Our aim is to tailor our processes to each type of industrial effluent to maximize its value.”**

### **What are the major tools that you are developing for use in the field?**

« We have compiled a catalogue of technology solutions describing the mineral precipitation processes that the Group utilizes. Each of our crystallization-precipitation processes has its own specific features. Through our studies, we have gained a better understanding of the mechanisms that each process brings into play. This has enabled us to define selection criteria to choose the process best suited for any given industrial application depending on the influent wastewater characteristics and the treated effluent discharge specifications.

We worked closely with the subsidiaries of Veolia Environnement to carry out this study, whose findings are now used to formulate bid proposals. Initially centered on sulfates, the program has now been extended to fluorides, phosphates and sulfites, as well as to carbonate removal.

Plant operators now can also use an online monitoring tool that permits more reliable management of paint booth effluents in the automotive industry. This tool optimizes process control by detecting certain types of anomalies. In fact, online monitoring guarantees optimal treated effluent quality, minimal VOC emissions, and sludge quality compatible with the requirements of final treatment.

Finally, the online tool for effluent variability analysis is now being vetted in the automotive industry after already being validated for use on chemical and steel industry effluents. »

### **What is the status of your efforts to optimize the recycling of surface treatment effluents?**

« Within the framework of the European Life Zeroplus project for the surface treatment industries, we have tested several processes already identified as Best Available Technologies (BATs). These projects recycle surface treatment effluents with results approaching Zero (Liquid) Discharge. We investigated the processes to determine which one is the most efficient in terms of recycling of the effluents for each step of the industrial process: grease removal, pickling, various types of rinsing and passivation baths. We are now in the validation phase, working with Galol, a company specializing in surface treatment. This program will ultimately enable us to implement a management model for surface treatment industry effluents. »



■ Membrane contactor pilot unit

