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Pilot plan for industrial wastewater treatment facilities in the objective of water reuse

Plan pilote pour les installations de traitement des eaux résiduaires industrielles en vue de la réutilisation de l'eau

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 282, *Water reuse*, Subcommittee SC 4, *Industrial water reuse*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Climate change impacts on water availability have industries across the globe seeking ways to drought-proof their operations. One of the key water conservation methods is to implement water treatment and reuse practices, simultaneously reducing demands on potable water resources and on industrial wastewater effluent discharges, and associated residual contaminants, to the environment. The greatest challenge to this approach lies in the characteristics of industrial wastewater and the water quality requirements for reuse, which vary significantly between industries and processes and are unique for each industrial operation. This variation depends on the type of process, raw materials, reagents and additives used, all resulting in a unique set of circumstances for each location, even within one industry. Therefore, industrial wastewater often requires unique treatment approaches, as well as the development and implementation of novel and innovative water treatment technologies.

To overcome this challenge, following a review of source control measures and water treatment alternatives, industries can choose to evaluate novel technologies using a scale-up study to transition the research-based laboratory-scale or bench-scale proof-of-concept treatment process into a functional demonstration or full-scale process. The use of a pilot plan for testing and evaluation of a novel technology or process is the focus of this document.

Pilot plant/facility is a relative term in the sense that it is typically smaller than a full-scale production plant. Still, it is built in a range of sizes and does not necessarily infer a small-scale application as it could be conducted at demonstration-scale or full-scale and often involves a significant investment of financial, equipment and labour resources; therefore, the term ‘pilot’ is relative. For new water treatment technologies emerging from laboratory and bench-scale development, pilot-testing is the first opportunity to establish or demonstrate commercial potential.

Pilot-testing can be used to check, on a reduced scale, a water treatment process developed through laboratory research. The experience gained by operating a pilot plant/facility can assist in making a decision as to whether or not to proceed with the full-scale plant by determining the likelihood of a full-scale successful implementation. Furthermore, pilot-testing provides for more reliable capital and operational cost estimates, and all necessary inputs (e.g. chemicals, power, labour resources), as well as the ease of operation and maintenance of a given water treatment process. Other objectives can be fulfilled simultaneously and some definitive considerations for the decision to build the pilot plant/facility are possible.

An industrial wastewater treatment pilot plan is a specific case of a chemical, physical and biological processing pilot plan. However, this type of treatment poses many unique challenges that need to be covered by the pilot plan. For example, because some industrial wastewater characteristics vary seasonally or are based on changes in industrial processing and product generation, it could be necessary to adjust or test different operating conditions and control strategies and settings to achieve the highest efficiencies and determine the most suitable economic operating conditions.

The concept of serviceability limit state (SLS) could be useful to determine these stress conditions. To satisfy SLS criterion, a facility ought to remain functional for its intended use (subject to routine operation conditions) after achieving SLS. A typical range of a ratio between the critical parameter values characterizing SLS and routine operation conditions (e.g. concentration of treated target contaminants, flow of wastewater stream, stream temperature) is 1,2/2, although it could be significantly higher for the modern robust wastewater treatment technologies.

The transition from laboratory-scale to a pilot-scale study requires detailed knowledge about the critical design and operating parameters, which initially does not exist and could include assumption making within an iterative process of refinement. The inability to replicate laboratory-scale research findings is often caused by failure to adequately scale-up critical process parameters. It is necessary that the principles of similitude to correlate model and prototype behaviour are carefully observed. Hydraulic similitude, commonly based on the Froude Number Law, is important, as it affects physical attributes such as energy dissipation, as well as dimensional analysis, thus establishing the basic relationship of the physical quantities involved in the dynamic behaviour of the treatment process. The physical, chemical and biological behaviour of the pilot process can simulate, in a known manner, the behaviour of the laboratory or bench-scale prototype, and similarly the behaviour of the pilot process can simulate that of a full-scale application. All scalability criteria and specific similitude requirements ought to be carefully defined prior to pilot planning.

Similarity assessment: since the similarity concept implies checking if the laboratory results are to be applicable to the real-life situation, as a rule, the initial conditions for the simulation correspond to the conditions of the performed laboratory research, whereas the boundary conditions correspond to the expected 'typical' future conditions. In some cases, the boundary conditions also include design limit states [e.g. SLS, fatigue limit state (FLS)] defined as the boundary conditions beyond which the tested technology/process/system fails (or could fail) to perform the function that is expected of it[3].

This document, with some necessary modifications and adjustments, can be used for comparative testing and analysis of the suitability of existing and proven commercial solutions to specific sites and applications (given, for example, operational conditions or specific requirements).

By the nature of dealing with the unexpected, any pilot plan represents a big challenge. Even a successful pilot plan cannot fully guarantee future success of full-scale implementation of tested solutions in real industrial conditions, for the following reasons:

— partial relevance of pilot conditions and environment to real full-scale conditions and environment (e.g. scale-up effects);

— partial coverage of tested pilot conditions of a spectrum of all possible full-scale states;

— short-term pilot performance (long-term effects, such as progressive failures as well as equipment-degraded performance due to ageing or seasonal effects, could hardly be evaluated in the framework of a pilot plan);

— uncertainty of statistical conclusions derived from rather limited collected pilot data;

— it could be that testing conducted at a single site of specific conditions will not represent the entire range of possible conditions characterizing other sites.

This document is not oriented towards a specific type of industrial process; use of raw materials, reagents and additives; or to a particular kind of wastewater. Rather, it provides comprehensive general guiding principles for pilot planning and performance to verify laboratory-scale findings and potential for commercialization. This document includes the critical considerations, methods, criteria and processes which need to be a part of every pilot plant study, from the initial planning through to the post-pilot analysis of the data collected during the pilot study.

A decision about performing a pilot plan ought to be made directly by all relevant stakeholders and interested parties. This document is therefore intended to provide the critical guidelines and considerations for successful implementation of a pilot plan.

Pilot plan for industrial wastewater treatment facilities in the objective of water reuse

1 Scope

This document provides the fundamental principles and guidelines for industrial wastewater treatment technology pilot studies.

It does not address laboratory research and development, study or testing of a given technology. It does not cover reuse applications or operations, such as irrigation.

This document applies to a wide range of industrial water treatment systems for the purposes of reuse.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20670, *Water reuse — Vocabulary*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20670 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
pilot plan
plan
programme
small (reduced) representative scale preliminary study, or a trial implementation and testing of a proposed solution (technology/process/processing chain), limited by some timeframe and conducted in predefined special conditions, in order to evaluate feasibility, effectiveness, efficiency, compliance and sustainability of this solution in an attempt to reveal all possible deficiencies and address them prior to performance of a full-scale project

Note 1 to entry: A pilot plan is a framework in which verification can be executed.

Note 2 to entry: For the purposes of this document, the terms *pilot plan*, *plan* and *programme* are used interchangeably.

3.2 Abbreviated terms

BoD	base of design
CSP	continuous sampling plan
DCS	distributed control system
DoE	design of experiments
DR	design review
FLS	fatigue limit state
FMEA	failure mode and effect analysis
HLD	high-level design
HSE	health, safety and environment
IQ	installation qualification
IT	information technology
LLD	low-level design
LLI	long lead items
NDCS	non-distributed control system
OQ	operational qualification
P&I	piping and instrumentation
PMBoK	project management body of knowledge
PMI	project management institute
PQ	performance qualification
QA	quality assurance
QC	quality control
RFP	request for proposal
R&R	repeatability and reproducibility
SLS	serviceability limit state
SOP	standard operating procedure
WBS	work breakdown structure

4 Lifecycle of a pilot study

4.1 General

To achieve the desired objectives, a pilot study requires a substantial investment, often including a long-term operation. A thorough analysis of the intended objectives and potential outcomes should be carried out before pilot-testing is carried out. The appropriate cost of constructing, operating and maintaining the pilot system should be weighed against the expected advantages to be gained in completing and meeting the pilot plan's objectives.

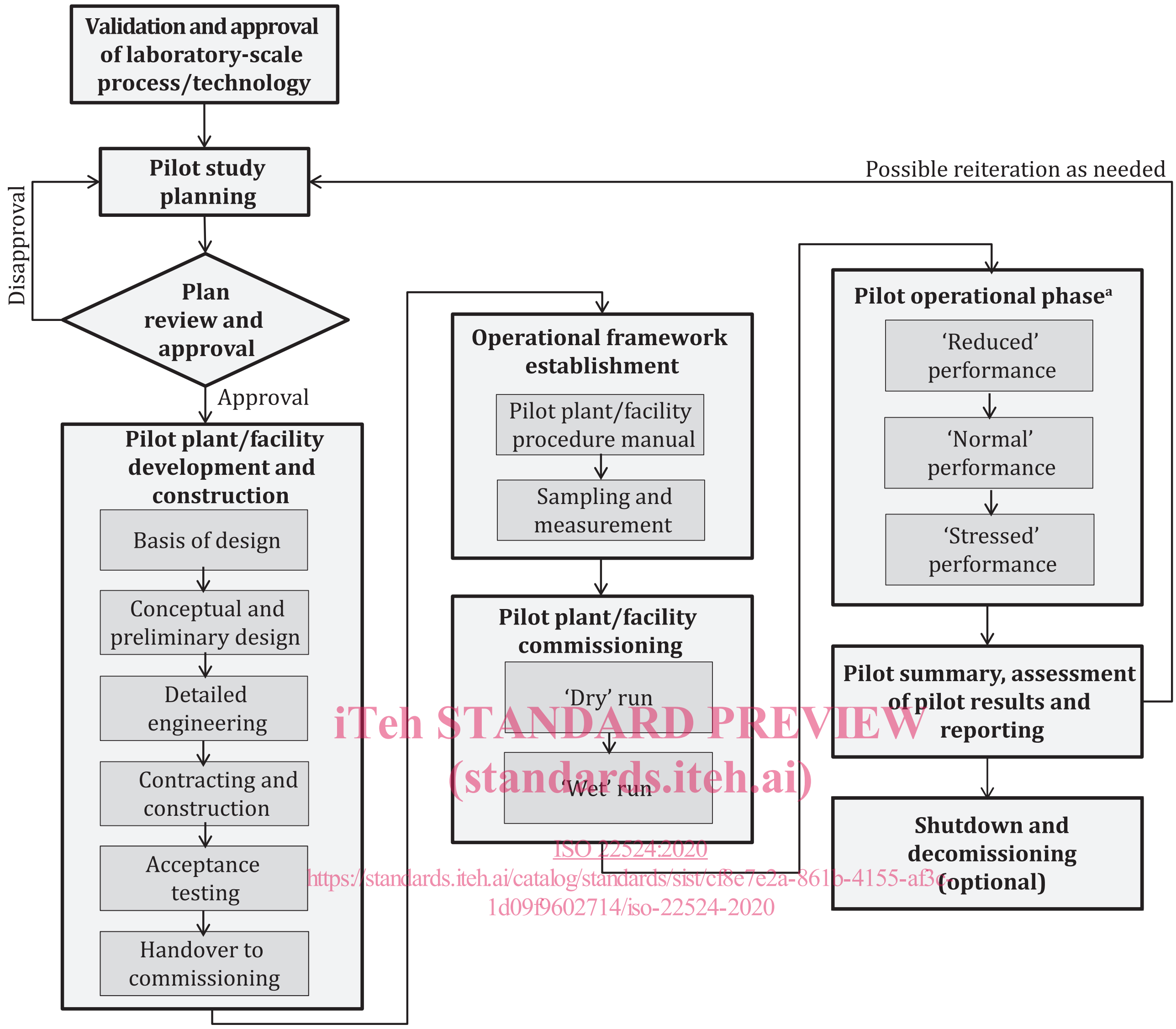
The decision about the performance of a pilot plan should be made directly by all relevant stakeholders and interested parties.

The knowledge and the experience obtained during performance of a pilot plan can be used for the design of full-scale water treatment systems and commercial products, as well as to identify further research objectives and to assist in reducing technical and financial risks associated with investment decisions. Pilot-testing of reclaimed water processes can also be used to demonstrate the effectiveness and robustness of the technology in protecting public and environmental health and safety and can also be useful in gaining public support for new technologies. They can also be used to train personnel for a full-scale plant.

4.2 Pilot plan lifecycle phases

4.2.1 General

In its lifecycle, a pilot plan may go through some or all of the phases depicted in Figure 1.



[a] Refer to 11.2, 11.3 and 11.4 for an explanation of the terms 'reduced', 'normal' and 'stressed' performance.

Figure 1 — Block-diagram of pilot plan phases

4.2.2 Statement of pilot plan goals

Pilot plan goals, scope and boundaries may be stated, based on the laboratory R&D outcomes, industrial wastewater characteristics and analysis of all relevant regulatory requirements, technology needs and constraints.

4.2.3 Pilot study programme

A pilot study (experiment) comprehensive programme may be established to ensure that the pilot plan results can be extrapolated and used for full-scale design purposes while minimizing the potential for process failure.

As an extension to laboratory research, the pilot plan should start with a study of the laboratory research findings and recommendations, and the process parameters determined during lab testing, with particular emphasis on critical aspects that have a significant impact on capital and operating costs.