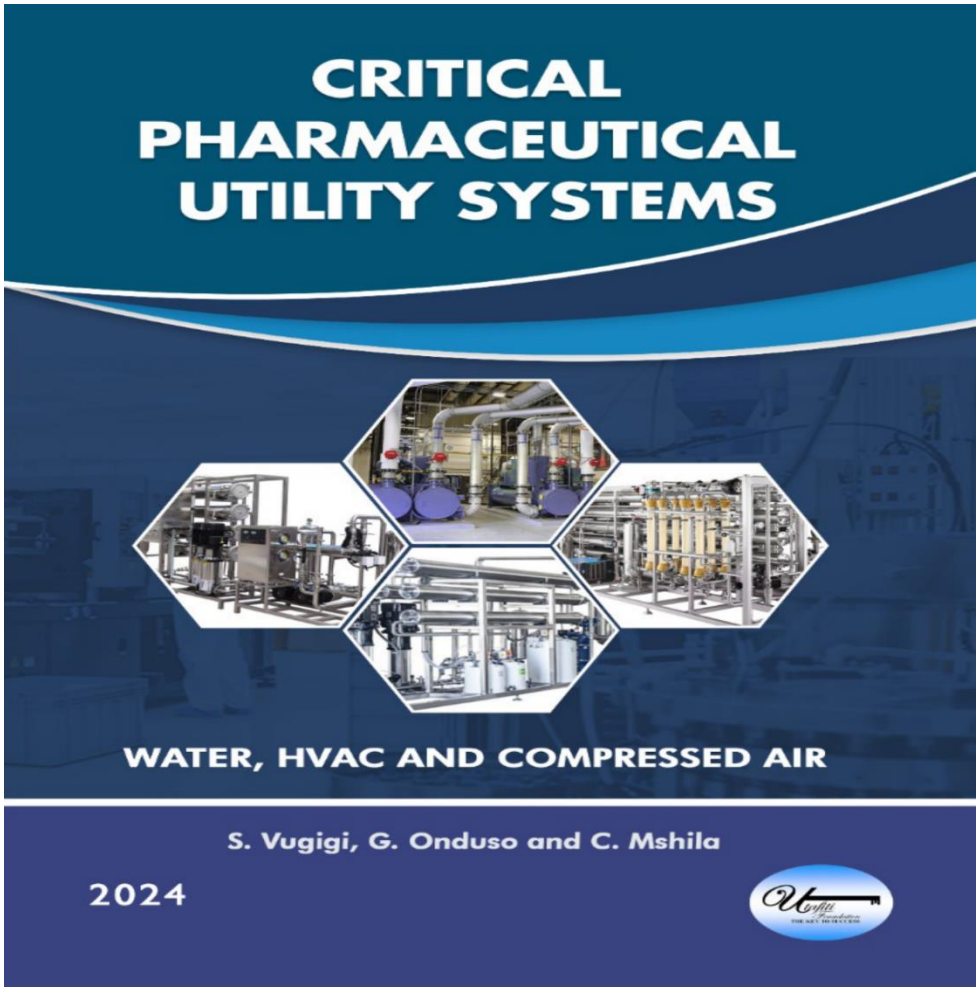

Critical pharmaceutical utilities are the core of production processes. This book covers, in detail, three critical utilities, namely, water, HVAC and compressed air. In addition, practical tools such as risk assessment techniques, protocols, audit checklists and maintenance worksheets are provided. The collaborative effort of the authors has produced a thorough text that is an invaluable resource for both undergraduate and postgraduate students, as well as pharmacists, engineers, and other scientists within the pharmaceutical and other related industries. Professionals in search of guidance on the design, qualification, and maintenance of critical utilities will find this book particularly beneficial.

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ABOUT THE AUTHORS

Sarah Vugigi, PhD, is a Senior Lecturer in Pharmaceutics at Kabarak University, Kenya. She holds a B. Pharm. degree from the University of Nairobi, an M. Pharm. (Iowa. USA) and a PhD. (Kenyatta University). She began her career as a Pharmaceutical Analyst at Drug Analysis Research Unit, Nairobi and later joined Cosmos Limited, Kenya, as Quality Control Head. She has held a part-time teaching position at Nairobi and Kenyatta Universities. She has extensive experience in pharmaceutical manufacturing processes, quality systems and regulatory affairs. She joined Kabarak, after 15 years of service at Elys Chemical Industries Ltd. as Head of Quality and Regulatory Affairs. She has published several manuscripts on pharmaceutical manufacturing, including the Kenya Pharmaceutical Investment Profile (2020) under Partnership for Investment and Growth in Africa project.

George Onduso is a United States based chemical engineer, with over 20 years of experience in the pharmaceutical industry. His expertise spans various areas including validation, project management, and process engineering. Currently he is the Principal Process Engineer at Nuclear Pharmaceuticals, Missouri, and involved in radiopharmaceutical process design and process transfer. He started his career at Cosmos Limited working as Quality Control Chemist. He holds a BSc. (Chemistry) from the University of Nairobi and a Chemical Engineering degree from the University of Minnesota, USA. He has worked at CSL Behring IL, Chicago as Validation Engineer, and Virbac Corporation, St Louis as Senior Pharmaceutical Process Engineer. He has applied his in-depth knowledge of pharmaceutical ventilation systems and clean rooms qualifications to elucidate the practical importance of HVAC systems.

Christian Mshila is a scientist and expert in quality control of pharmaceutical products. He has 25 years of experience in quality control, including qualification of critical utility systems. Currently, he is Quality Control Manager at Elys Chemical Industries Ltd. Kenya. In addition to developing and implementing quality control processes, he is a GMP trained member of the Unit's Quality Team that is concerned with process improvement and regulatory compliance. He graduated from the University of Nairobi with first - class honors in analytical chemistry in 1998 and started his career as a Quality Control Chemist at Cosmos Limited. Later, he worked for Regal Pharmaceuticals Ltd. as Quality Control Manager.

FOREWORD

In the pharmaceutical industry, the quality and reliability of three critical utilities: water, HVAC (heating, ventilation and air conditioning), and compressed air, are of paramount importance. Water plays a vital role in various processes such as cleaning, formulation, and as a key ingredient in drug products. HVAC systems are essential for maintaining controlled environments that adhere to strict temperatures, humidity, and air quality standards to ensure the integrity and stability of pharmaceutical products. Compressed air is used in a wide range of pharmaceutical operations, including equipment cleaning, product conveying, and packaging. The design and operation of critical utilities requires a blend of pharmaceutical and engineering knowhow. Often, personnel are employed in the industry with a knowledge gap on these critical utilities and they are trained on the job by experts with experience.

This book provides a comprehensive presentation of these three critical utilities, exploring their significance in regulatory requirements, pharmaceutical manufacturing, best practices for design and qualification, maintenance strategies, and emerging trends in the industry. The authors are pharmaceutical manufacturing industry experts who have combined their long and varied experience in the industry to tackle the topic, and hence provide a guide for both training and practice.

You will find a combination of focused in-depth discussions, practical examples and insight to guide you through the complex landscape of critical pharmaceutical utilities. By understanding the importance of these utilities and adopting best practices, manufacturers can ensure the safety, efficacy, and quality of pharmaceutical products. Furthermore, the content can also be applied to extemporaneous production units, chemotherapy preparation suites in hospitals, and facilities in the food industry.

This book should serve as a valuable reference of professionals in the pharmaceutical industry, academia, regulatory agencies, and anyone interested in gaining a deeper understanding of the indispensable role that water, HVAC, and compressed air play in pharmaceutical manufacturing. Whether you are a seasoned professional looking to deepen your knowledge or a newcomer seeking to understand the foundational principles, this book is a valuable resource for all stakeholders involved in pharmaceutical manufacturing.

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PREFACE

The term “utility” in the pharmaceutical industry refers to infrastructure-based systems such as water that are essential components of a manufacturing process. Critical utilities are those utilities that can have a direct impact on product safety and quality and are treated as materials which must meet regulatory and manufacturing standards. Efficient operation of critical utilities is the core of a manufacturing process; hence critical utilities is a key topic in industrial pharmacy. This book covers, comprehensively, three critical pharmaceutical utilities namely, water, Heating, Ventilation, and Air Conditioning (HVAC) and compressed air. The content herein is founded on Good Manufacturing Practice (GMP) guidelines for critical pharmaceutical utilities, theoretical aspects in designing and construction of these utilities and anchored on academic–cum-practitioner's understanding of the competency requirements for the pharmaceutical manufacturing sector. Control of critical utilities requires a multi-disciplinary approach as it cuts across engineering, production, regulatory, quality control testing and quality assurance operations. The industrial pharmacist involved in any of these departments is expected to have sufficient knowledge of the utilities starting from the regulatory requirements, design considerations, generation process, quality control testing procedures, system qualification and monitoring. This book is valuable not only to undergraduate and industrial pharmacy students, but also as a reference text for industrial pharmacists, engineers and other scientists within pharmaceutical manufacturing sector.

The first section of the book presents an introduction to pharmaceutical regulation, highlights its paramount importance in ensuring the safety, efficacy, and quality of pharmaceuticals. Critical utilities are subjected to GMP requirement, which is an important aspect of drug regulatory authority inspection universally. The goal is to protect the health and well-being of individuals while fostering innovation in the pharmaceutical industry. Understanding regulatory requirements is fundamental in designing a compliant critical utility system. Critical systems must be designed based on Good Engineering Practices, covering the lifecycle of engineered systems. A brief introduction of the three critical utilities in focus is included here.

The second section looks at pharmaceutical water systems. It comprises four subsections namely, industrial raw water, pharmaceutical waters, purification, and validation of water systems. The content herein includes raw water sources, water contaminants, microbial pathogens, biofilms and related risks, types of pharmaceutical waters, types of water for specific production processes, water pretreatment techniques, water purification methods, distribution, sampling points, quality control testing, system sanitization, and considerations in selection of a water purification method. The system qualification process starting from user requirements specification documentation, design qualification, installation qualification, operational qualification and performance qualification are expounded.

Section three addresses compressed air under the topics: pharmaceutical application, compressed air quality standard, production of compressed air, types of compressors,

qualification of compressed air systems and quality control tests. Samples of validation protocols and GMP inspection checklists are provided.

The final section explores the importance of HVAC systems in pharmaceutical facilities in maintaining a safe and fully operational environment within production areas and more. It focuses on design considerations, compliance requirements, and their critical influence on product quality. It explains the role of pharmaceutical HVAC systems, clean room strategy, HVAC design considerations, HVAC design for specific processes; sterile, non-sterile, radiopharmaceutical, URS for HVAC, qualification and validation of the system and preventive maintenance procedures. This section has elaborate HVAC diagrams, engineering calculations, practical applications, and examples from a practitioner's perspective.

In addition to the required knowledge on critical utilities, this book contains useful tools such as protocols for operationalization of the theoretical aspects, risk assessment tools for decision making, URS documents preparation, quizzes and utility inspection checklists which are included as appendices.

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