

Methods for faecal sludge analysis

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Dr. Linda Strande leads a research group at Eawag (Swiss Federal Institute of Aquatic Science and Technology), in Sandec (Department Sanitation, Water and Solid Waste for Development). Her focus is globally relevant solutions for sustainable city-wide sanitation, through developing fundamental scientific knowledge, translating it to innovative technology solutions, and ensuring uptake through implementation strategies. Current research includes governing mechanisms controlling dewaterability, affordable methods for characterisation and quantification, optimization of treatment technologies, and innovation in resource recovery. Dr. Strande has been working in the WASH sector for over 20 years, has had research collaborations with local and international stakeholders from over 20 countries, and published over 60 international, refereed publications. She is passionate about mentoring upcoming generations of engineers and practitioners, and has had over 10,000 learners in her online course in faecal sludge management. She is a founding member of the SFD Promotion Initiative and FSM conferences, a contributor to the WHO Guidelines on Sanitation and Health, World Bank FSM Tools, and lead editor of the IWA Publishing book Faecal Sludge Management: Systems Approach for Implementation and Operation. Her wide-ranging international experiences have given her a global perspective, and an ability to research and apply engineering fundamentals in complex, interdisciplinary situations.



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Dr. Mariska Ronteltap is an environmental engineer from Wageningen University. After a few consulting years she pursued a PhD at Eawag (the Swiss Federal Institute of Aquatic Science and Technology) and ETH (Swiss Federal Institute of Technology), specialising in resource recovery from sanitation. In 2006 she joined IHE Delft Institute for Water Education (formerly UNESCO-IHE), the Netherlands. She developed a large quantity of new teaching material and initiated research in the field of resource recovery and non-sewered sanitation, and inspired many students, practitioners and decision makers to make sanitation a priority. Dr. Ronteltap mentored in excess of 40 MSc students and 3 PhD fellows. With more than 1,500 citations and publications of high impact, her work is globally recognized; she has been invited as speaker to several conferences and was one of the editors of the book *Faecal Sludge Management: Systems Approach for Implementation and Operation* published by IWA Publishing. She is a member of the management team of the IWA Specialist Groups on Resource Oriented Sanitation and Non-sewered Sanitation, of the Circular Water Technology of the Royal Dutch Water Network, and of the Program Committee on Wastewater of the Foundation of Applied Water Research (STOWA). Dr. Ronteltap currently works for Delfland Water Authority in The Netherlands as a senior wastewater expert and technology innovator and she continues to teach, publish, present and supervise students.



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Prof. Damir Brdjanovic, PhD

Dr. Damir Brdjanovic is Professor of Sanitary Engineering at IHE Delft Institute for Water Education and Endowed Professor at Delft University of Technology. Areas of his expertise include pro-poor and emergency sanitation, faecal sludge management, urban drainage, and wastewater treatment. He is a pioneer in the practical application of models in wastewater treatment practice in developing countries. He is co-inventor of DEMOS[®]: Digital Epidemic Observatory and Management System, and of the Shit Killer[®] device for excreta management in emergencies, the award-winning eSOS[®] Smart Toilet and the medical toilet MEDiLOO[®], with funding by the Bill & Melinda Gates Foundation (BMGF). He has initiated the development and implementation of innovative didactic approaches and novel educational products (including e-learning) at IHE Delft. Brdjanovic is co-founder and director of the Global Sanitation Graduate School and co-founder of Global Partnership of Laboratories for Faecal Sludge Analysis. In addition to dozen of PhD students, in excess of 150 MSc students have graduated under his supervision so far. Prof. Brdjanovic has a sound publication record, is co-initiator of the IWA Journal of Water, Sanitation and Hygiene for Development, and is the initiator, author and editor of eight books in the wastewater treatment and sanitation field. In 2015 he became an IWA Fellow, in 2018 received the IWA Publishing Award, and in 2019 IWA Water and Development Research Award 2019 Runner Up.



Prof. Chris Buckley

Chris Buckley is a Research Professor and Head of the Pollution Research Group at the University of KwaZulu-Natal (UKZN PRG). He is a chemical engineer, a Professional Engineer and a Fellow of IWA. He has been a member of the ISO/ANSI/SABS panel for the development of ISO30500 standards, Chair of the Water SA journal editorial board and a member of numerous Water Research Commission (WRC) project reference groups. Prof. Buckley's public sector activities have been directed for decades to providing water and sanitation services to the 'unserved'. Since 2009 he and his team have participated in a number of Bill & Melinda Gates Foundation (BMGF) projects related to sanitation for the poor (including the flagship Reinvent the Toilet Challenge program). The current grant has provided a fully staffed, dedicated faecal sludge laboratory and an engineering field testing platform for reinvented toilets and other advances in real-world conditions with the aim to facilitate the roll-out of innovative pro-poor WASH solutions. He has supervised more than 100 Master and PhD students and his current research projects are funded by the WRC, BMGF, Emory University, Swiss Development Cooperation, Swedish Research Council, National Science Foundation with San Diego State University, and IHE Delft. Because of his dedicated work in sanitation, Prof. Buckley describes himself as a 'Shit Manager'; he continues to inspire generation of young professionals to join the sanitation field.

Foreword

Since 2015, with the adoption of the Sustainable Development Goals (SDGs) by the United Nations (UN), the importance of non-sewered sanitation service provision and the major inequalities of sanitation service delivery have been highlighted. In 2017 the Joint Monitoring Program (JMP) of the UN and the World Health Organisation (WHO) estimated that around 4.2 billion people, or 55% of the global population, did not have access to safely managed sanitation. This is the equivalent of 6 people out of 10, with the vast majority living in developing countries, in communities where sewer-based approaches are not feasible, practical, or too expensive.

For several decades, attempts to develop sanitation solutions in developing countries focused on adapting treatment solutions from centralised, sewer-based management solutions. These approaches assumed that faecal sludge characteristics are similar to those of sewage or urban wastewater. As a result, several treatment plants and technologies resulted in failure, and did not meet communities' need for the protection of public health, as they were designed based on the wrong assumptions.

However, since 2011 we have seen a growing number of academic institutions, industries, and sector professionals engaging in the development of sanitation solutions that meet the needs of communities relying on non-sewered sanitation solutions. This growing community is among the target audience for this book.

These global efforts have inspired some strategic organisations and platforms that are serving the non-sewered sanitation community. In 2011 several leading organisations in non-sewered sanitation supported the creation and the establishment of the Faecal Sludge Management (FSM) conference series to help consolidate and disseminate best practices. These conferences continue to be supported by the Faecal Sludge Management Alliance (FSMA). The Toilet Board Coalition launched a business-led partnership and platform in 2015 that has the ambition

to address the global sanitation crisis by accelerating the Sanitation Economy through enabling private sector engagement and collaboration between private, public and non-profit sectors. In 2016, 24 organisations launched the Indian National Faecal Sludge and Sewerage Alliance with the goal of sharing best practices on non-sewered sanitation. The Pan-African Association of Sanitation Actors (PASA) was launched in 2019 by pit latrine emptiers in Africa (non-sewered sanitation service providers), in partnership with the African Water Association (AfWA, the water and sanitation utility operators), to better organise their industry and business. In 2018 the Global Sanitation Graduate School (GSGS) initiative managed by IHE Delft Institute for Water Education was launched with the aim to establish reference training centres in national universities in developing countries; this program supports the next generation of academic leaders in the development of sustainable solutions for communities on city-wide inclusive sanitation (CWIS) systems. Also in 2018 the Global Partnership of Laboratories for Faecal Sludge Analysis (GPLFSA) was established to improve the communication between different faecal sludge laboratories and to address together challenges related to analysis of faecal sludge and the generation of a uniform database for faecal sludge characteristics. Most recently, in 2019 the International Water Association (IWA) launched a new specialist group on non-sewered sanitation, with the focus to consolidate the generation of technical and scientific evidence on faecal sludge management solutions.

This book consolidates three decades of evidence gathering on methods for sampling and analysing faecal sludge collected from non-sewered sanitation facilities. It addresses the needs of inventors who are working on innovative sanitation technologies such as systems that meet ISO 30500 and ISO 31800 specifications, new pit emptying technologies or decentralised faecal sludge processing technologies for resource recovery. The chapter on faeces simulants is particularly designed to help inventors and laboratories that do not have access to testing facilities

with raw human excreta and also for replication in scientific studies. For national and university analytical laboratories and researchers, the book provides a step-by-step approach to upgrade faecal sludge analytical laboratories. For conformity assessment laboratories and standardisation bodies, this book will serve as a reference for methods to test technology performance and compliance with standards. National programs focusing on accelerating access to non-sewered sanitation will find references in the book to develop analytical capabilities and reference to training materials.

The authors have compiled the latest data to fill an important gap for the sanitation sector, as the chapters highlight strong scientific evidence on why and how faecal sludge differs to sewage, and provide clear recommendations for sampling and analytical methods. These recommendations are derived from a consensus of global leading academic centres: the University of KwaZulu-Natal (South Africa), the Asian Institute of Technology (Thailand), the Swiss Federal Institute of Aquatic Science and Technology - Eawag (Switzerland) and the IHE Delft Institute for Water Education (Netherlands).

My special thanks go to Dr. Konstantina Velkushanova and the team at the University of KwaZulu-Natal for coordinating the edition and publication of this reference book. As the community of sanitation professionals grows, it is my expectation that this book will be regularly updated to capture new evidence and stand as a reference for the community, and for the growing number of sanitation industry players.



Dr. Doulaye Koné

Bill & Melinda Gates Foundation

Preface

Until recently, publishing on the topic of faecal sludge from onsite sanitation systems (known as the *unserved*) has been a neglected area. On the other hand, the topic of water supply for the previously *unserved* has been well covered by many publications by different authors and organisations. Some of the early publications in the field were related to aid agencies and humanitarian organisations, and these publications focused on practical planning, construction, implementation and maintenance. (e.g. Unicef, WaterAid, Oxfam). Publications on urine separation were motivated by environmental improvement and sustainability issues and generally focused on the health, social acceptance and agricultural aspects (Stockholm Environment Institute - SEI, German Corporation for International Cooperation GmbH - GIZ, IHE Delft Institute for Water Education - IHE Delft). The *Compendium of Sanitation Systems and Technology* from Eawag (the Swiss Federal Institute of Aquatic Science and Technology) marked the start of publications in faecal sludge, followed by the book *Faecal Sludge Management: Systems Approach for Implementation and Operation*, published collaboratively between Eawag and IHE Delft.

The Bill & Melinda Gates Foundation (BMGF) research programme into sanitation started by funding sanitation programmes for the unserved at Eawag, London School of Hygiene and Tropical Medicine, Asian Institute of Technology (AIT) and IHE Delft. The faecal sludge management (FSM) conference series initiated by the South African Water Research Commission (WRC) was the start of regular conferences on the topics which brought researchers and practitioners together. Up to this point, the main reference source for sampling, analytical methods and data interpretation was the well-known and frequently updated publication: *Standard Methods for the Examination of Water and Wastewater*¹. The Reinvent the Toilet Challenge in 2011 brought a whole range of

new researchers into the wonderful world of faecal sludge management. During the different events and convenings which were organised for the sharing of the results from these inventions, the question of different synthetic simulants, characterisation techniques and appropriate methods of analysis became a heated discussion point. The need for a *common language* became evident.

The conception and framing for this book was the end result of such discussions which were being held in parallel whenever FSM researchers got together and data was being exchanged. The editorial team came together on many occasions in different parts of the world and finally this publication came out as the first step towards the development of mutually agreed methods for faecal sludge analysis.

The finalisation of the two ISO standards related to non-sewered sanitation (ISO 30800 and ISO 31800) will be the spur for future updates in order to ensure the analytical methods keep up with the new and emerging technologies employed in the novel systems. The first intention of editors was to focus on a joint publication of methods for laboratory-based faecal sludge analysis but during the course of content development, it was identified the necessity to expand the scope and share important practical developments in the field, divided into eight chapters of the book. These include setting the scene, innovations and current trends in the field (Chapter 1), considerations for the measurement of properties and characterisation of faecal sludge (Chapter 2), different methods and techniques for faecal sludge sampling and handling (Chapter 3) and practical tips of how to set up a laboratory experimental design in a meaningful way to be able to support the design improvement of large-scale treatment technologies (Chapter 4). It is also discussed the importance and knowledge required to estimate the qualities and quantities at scale - from community to city-wide (Chapter 5), and modelling

¹ Rice E.W., Baird R.B. and Eaton A.D. (eds.) (2017). *Standard Methods for the Examination of Water and Wastewater*, 23rd edition. *American Public Health Association, American Water*

frames and approaches of faecal sludge processes taking place in the containments (Chapter 6). The importance of faecal sludge simulants and their use for technology development testing has also been provided along with examples of faecal sludge simulants for different purposes (Chapter 7). A guideline and considerations of how to set up a faecal sludge laboratory are provided along with case studies of already established faecal sludge laboratories (Chapter 2) and other partnering organisations under the Global Partnership of Laboratories for Faecal Sludge Analysis (GPLFSA)². This consortium consists of laboratories to address the current challenges in the field and continuously work towards standardisation of methods for faecal sludge characterisation and quantification (Annex 1). The GPLFSA falls under the umbrella of the Global Sanitation Graduate School³ (GSGS) platform committed to capacity building and knowledge dissemination in the field of faecal sludge management through postgraduate programs, online and campus-based courses and training programmes, aiming to improve the communication between sanitation practitioners, provide a comparative faecal sludge database, and greater confidence in the methods and obtained results. The GSGS and GPLFSA play a central role as dissemination platforms of this book.

The book is not necessarily intended to be read from cover to cover, but consulted as the need arises. The editors aim at a wide audience, represented by researchers and students, laboratory personnel and practitioners.

Students new to faecal sludge will find chapters 1, 2, 3 and 4 particularly useful for orientating themselves into the quantitative issues of the topic. City planners, designers and consultants will find chapters 5 and 6 essential reading. Researchers will be continually consulting all chapters of the book depending on the phase of the research being undertaken at the time. Laboratory personnel will be particularly interested in Chapter 8 augmented with information from chapters 2 and 3. Regulators will be guided by chapters 2, 5 and 6 to set standards and guidelines based on techniques in Chapter 8. Practitioners and developers of new technologies will find chapters 1, 2, 3, 4 and 8 particularly useful.

The editorial team have learnt a lot during the journey of collating this information and sincerely hopes it is of value to all involved in the important task of faecal sludge management. During this concerning period of the COVID-19 pandemic and the detection of SARS-CoV-2 RNA it is realised that this publication is not the final word in this important field and edited versions will be issued when the need arises.

Prof. Chris Buckley

University of KwaZulu-Natal

² <https://sanitationeducation.org/laboratories/>

³ <https://sanitationeducation.org/>

Acknowledgements

The inspiration for this book originated a few years ago following conversations between different practitioners in the faecal sludge management field, and the realisation of the importance of having a standardised approach for the analysis, sampling and handling practices of faecal sludge. Back then, different groups of professionals and academics were working individually on the development of internal and standard operating procedures, so bringing this knowledge and experience together into a single publication was a major step forward to set the foundation needed for the development of standard methods for faecal sludge analysis.

The Methods for Faecal Sludge Analysis book is truly a team achievement. Therefore, I would like to extend my gratitude towards the editorial team for their never-ending enthusiasm, creativity, dedication, and inspirational approaches in dealing with the issues we encountered. Particularly, I would like to thank Dr. Linda Strande and Prof. Damir Brdjanovic for their unstinting support and mentorship throughout the entire period of the book development. Dr. Strande and the MEWS team from Eawag/Sandec made an excellent and invaluable contribution to the writing, editing and production of all the chapters in the book. Prof. Brdjanovic played a crucial role in the editing and coordinating the technical production of the book.

I would like to extend my thanks to the entire team of the Pollution Research Group (WASH R&D Centre¹) of the University of KwaZulu-Natal for their endless support in the delivery of this book, including editing, authorship, managerial and moral support. Particularly I would like to recognize the importance of the mentorship of Prof. Chris Buckley who was the real inspiration to start my work in this field. I wish to express my gratitude to the most important people - the international group of authors, contributors and reviewers who produced, contributed and carefully reviewed one or more chapters of the book. A vote of thanks goes to the English editor, Ms. Claire Taylor, for her high level of professionalism and excellence, to the graphic designers of Synopsis d.o.o., and to IWA Publishing for their support in the publication of the book, particularly Mr. Rod Cookson, Mr. Mark Hammond, and Mr. Niall Cunniffe. Last but not least, I would like to thank the funders of this project - the Bill & Melinda Gates Foundation. Particularly I would like to thank the project's programme officer Dr. Carl Hensman and Dr. Doulaye Koné for trust and continuous support. Without their support this book would not have been possible.

I hope that you will enjoy reading this book as much as we enjoyed writing it.

Dr. Konstantina Velkushanova

IHE Delft Institute for Water Education

¹ The Pollution Research Group at the University of KwaZulu-Natal (UKZN PRG) has been rebranded to Water, Sanitation and Hygiene Research and Development Centre (WASH R&D Centre) since December 2020. The rebranding occurred during the advanced stage of production and as such has not been reflected further in this book.

Table of contents

1. SETTING THE STAGE	1
1.1 City-wide inclusive sanitation	2
1.2 What is faecal sludge?	3
1.3 Towards standardisation of methods for faecal sludge analysis	6
1.4 Integrated approach to data collection	7
1.5 Additional resources	9
2. FAECAL SLUDGE PROPERTIES AND CONSIDERATIONS FOR CHARACTERISATION	15
2.1 Introduction	16
2.2 Types of faecal sludge	16
2.3 Factors influencing the faecal sludge characteristics along the sanitation service chain	18
2.3.1 Inputs to faecal sludge production	19
2.3.1.1 Excreta	19
2.3.1.2 Water inputs	19
2.3.1.3 Annual cleansing materials	21
2.3.1.4 Additional inputs	21
2.3.2 Factors affecting characteristics of accumulated faecal sludge	21
2.3.2.1 Technical factors	22
2.3.2.2 Demographic factors	22
2.3.2.3 Environmental factors	23
2.3.2.4 Variability of accumulated faecal sludge	23
2.3.2.5 Developments and innovations in onsite containment	24
2.3.3 Emptying and transport	26
2.3.3.1 Storage time or emptying frequency	26
2.3.3.2 Manual or mechanical emptying	27
2.3.3.3 Transportation	27
2.3.3.4 Innovations in faecal sludge emptying and transportation	27
2.3.4 Treatment and end use	28
2.3.4.1 Faecal sludge treatment plants	28
2.3.4.2 End use or disposal	30
2.3.4.3 Innovations in treatment and end use	30
2.3.4.4 Container-based sanitation (CBS)	31
2.3.4.5 Summary of technologies along the sanitation service chain	31
2.4 Properties of faecal sludge and selecting methods of characterisation	34
2.4.1 Faecal sludge properties	35
2.4.1.1 Chemical and physico-chemical properties	35
2.4.1.2 Physical properties	37
2.4.1.3 Biological properties	37
2.4.2 Selection of appropriate methods for characterisation	38

2.5	Setting up laboratories for faecal sludge analysis	39
2.5.1	Faecal sludge laboratory workflow	40
2.5.2	Health and safety practices	41
2.5.3	Laboratory management systems	41
2.5.4	Case studies of global faecal sludge laboratories	43
2.5.5	Global Partnership of Laboratories for Faecal Sludge Analysis (GPLFSA)	48
2.6	Outlook	48
3.	FAECAL SLUDGE SAMPLE COLLECTION AND HANDLING	55
3.1	Introduction	56
3.2	Sampling objective	56
3.2.1	Containment	56
3.2.2	Collection and transport	57
3.2.3	Treatment	57
3.2.4	End use	57
3.3	Representativeness	58
3.4	Sampling techniques	58
3.4.1	Grab sampling	58
3.4.2	Composite sampling	59
3.5	Sampling and measuring devices	60
3.5.1	L-stick sludge and scum measuring device	62
3.5.2	Core sampling device	62
3.5.3	Vacuum sludge sampling device	63
3.5.4	Cone-shaped sampling device	64
3.5.5	Grab sampling device - horizontal	65
3.5.6	Grab sampling device - vertical	65
3.5.7	Automatic composite sampler	66
3.5.8	Distance laser measuring device	66
3.5.9	Portable penetrometer	67
3.6	Sampling methods and location	68
3.6.1	Sampling <i>in situ</i> from onsite containment technologies	68
3.6.2	Sampling during emptying of onsite containment technologies	71
3.6.3	Sampling at faecal sludge treatment plants	76
3.7	Sample size	78
3.8	Health and safety	79
3.9	Sample collection	80
3.10	Recording of sample collection	81
3.11	Transport	82
3.12	Storage and preservation	82
3.13	Example of sampling kit	82
3.14	Outlook	83

4. EXPERIMENTAL DESIGN FOR THE DEVELOPMENT, TRANSFER, SCALING-UP, AND OPTIMISATION OF TREATMENT TECHNOLOGIES: CASE STUDIES OF DEWATERING AND DRYING	85
4.1 Introduction	86
4.2 Experimentation in faecal sludge management	87
4.2.1 Scales of experiments	87
4.2.2 Designing an experiment	88
4.3 Transferring technology: conditioning to improve dewatering	89
4.3.1 Introduction to faecal sludge dewatering with conditioners	89
4.3.2 Types and mechanisms of conditioners	90
4.3.3 Key parameters for selection of conditioners and optimal dose	91
4.3.4 Laboratory- and pilot-scale testing	91
4.3.5 Case studies - conditioning for improved dewatering	92
4.4 Transferring technology: thermal drying for resource recovery of dried sludge for energy	98
4.4.1 Introduction to resource recovery of faecal sludge as solid fuel	98
4.4.2 Introduction to faecal sludge drying	98
4.4.3 Types and mechanisms of thermal drying (technical background)	99
4.4.4 Key parameters when implementing thermal-drying technologies	101
4.4.5 Laboratory-scale and pilot-scale testing	102
4.4.6 Case studies - thermal drying for energy recovery	103
4.5 Transferring technology: microwave drying for resource recovery of dried sludge for energy	108
4.6 Outlook	122
5. ESTIMATING QUANTITIES AND QUALITIES (Q&Q) OF FAECAL SLUDGE AT COMMUNITY TO CITY-WIDE SCALES	115
5.1. Introduction	116
5.2 Background	117
5.2.1 Scenario projections for planning and management	117
5.2.2 Mass balance: quantifying loadings of faecal sludge	119
5.2.2.1 Production of excreta and faecal sludge	120
5.2.2.2 Accumulation of faecal sludge	120
5.2.2.3 Fate of faecal sludge	122
5.3 Steps for implementation	122
5.4 Further research and analytical possibilities	136
5.4.1 Remote sensing	136
5.4.2 Additional spatial analysis	136
5.4.3 Interrelationships between sludge characteristics	136
5.4.4 Evaluating categories of data to evaluate separately	138
5.4.5 Predictive models	139
5.4.6 Sensitivity analysis and error propagation	139
5.5 Outlook	141

6. TOWARDS CITY-WIDE INCLUSIVE SANITATION (CWIS) MODELLING: MODELLING OF FAECAL SLUDGE CONTAINMENT/TREATMENT PROCESSES	145
6.1 Background	146
6.2 Introduction to modelling - learning from activated sludge models	148
6.2.1 What is a model?	148
6.2.2 Modelling basics	151
6.2.2.1 Model building	151
6.2.2.2 General activated sludge model set-up	152
6.2.2.3 The matrix notation	154
6.2.2.4 Wastewater treatment models	155
6.2.2.5 Modelling protocols	156
6.3 Towards an onsite sanitation modelling framework	160
6.3.1 Onsite sanitation modelling: formulation of objectives	160
6.3.2 Onsite sanitation modelling: process description	160
6.3.2.1 Portable toilets	161
6.3.2.2 Single pit latrines	162
6.3.2.3 Septic tanks	164
6.3.3 Onsite sanitation modelling: data collection and verification	168
6.3.4 Onsite sanitation modelling: model structure	171
6.3.4.1 Model structure of commonly used onsite sanitation systems	171
6.3.4.2 Model structures of other sanitation systems	174
6.3.5 Onsite sanitation modelling: characterisation of flows	175
6.3.6 Onsite sanitation modelling: calibration and validation	177
6.3.7 Onsite sanitation modelling: detailed characterisation	177
6.3.7.1 Faecal sludge characterisation and fractionation	177
6.3.7.2 Inhibition and toxicity	179
6.3.7.3 Pathogen inactivation	180
6.3.8 Modelling applications, benefits and challenges	184
6.4 Outlook	185
7. FAECAL SLUDGE SIMULANTS: REVIEW OF SYNTHETIC HUMAN FAECES AND FAECAL SLUDGE FOR SANITATION AND WASTEWATER RESEARCH	195
7.1 Introduction	196
7.2 Characteristics of faeces and faecal sludge	197
7.2.1 Faeces	197
7.2.2 Faecal sludge	198
7.3 Synthetic faeces and faecal sludge found in literature	204
7.3.1 Physical parameters	204
7.3.1.1 Faeces simulants	204
7.3.1.2 Faecal sludge simulants	206
7.3.2 Chemical, biological, and thermal parameters	207
7.3.2.1 Faeces simulants	207
7.3.2.2 Faecal sludge simulants	209

7.4 Discussion	211
7.4.1 Development of new simulants	214
7.4.1.1 Synthetic faeces	214
7.4.1.2 Synthetic faecal sludge	216
7.5 Conclusions	216
8. LABORATORY PROCEDURES AND METHODS FOR CHARACTERISATION OF FAECAL SLUDGE	235
8.1 Introduction	236
8.2 Health and safety (H&S)	238
8.2.1 Monitoring and responsibilities	238
8.2.2 Standard operating procedures (SOPs)	239
8.2.3 Handling of faecal sludge	241
8.2.3.1 Personal protective equipment	241
8.2.3.2 Vaccinations / inoculations	242
8.2.3.3 'Clean' and 'dirty' work areas	242
8.2.3.4 Sampling	242
8.3 Quality assurance and quality Control (QA/QC)	242
8.3.1 Training	243
8.3.2 Standard operating procedures	243
8.3.3 Laboratory facilities	243
8.3.4 Sample chain of command	244
8.3.4.1 Laboratory photographs and notebooks	244
8.3.4.2 Equipment maintenance and calibration	245
8.3.4.3 Reporting of results	246
8.3.4.4 Checking compliance	246
8.3.5 Quality control	247
8.4 Selection of the appropriate method for the purpose of characterisation	249
8.4.1 Faecal sludge storage and preservation	251
8.4.2 Faecal sludge sample preparation for analysis	251
8.2.4.1 Homogenisation of samples	252
8.2.4.2 Dilution of samples	252
8.2.4.3 Filtration	253
8.2.4.4 Centrifugation	253
8.4.3 Sample and chemical disposal	253
8.5 Shipping and receiving of faecal sludge samples and equipment	254
8.6 Chemical and physico-chemical properties	257
8.6.1 Solids and moisture content	257
8.6.1.1 Total solids and moisture content - volumetric and gravimetric methods by oven drying	257
8.6.1.2 Volatile and fixed solids - ignition method	260
8.6.1.3 Total suspended solids and total dissolved solids - oven drying method	263
8.6.1.4 Volatile suspended solids - ignition method	266

8.6.1.5	Total solids and moisture content - thermal balance (moisture analyser) method	268
8.6.1.6	Sand content	269
8.6.2	Chemical oxygen demand (COD)	271
8.6.2.1	Chemical oxygen demand - closed reflux spectrophotometric method	271
8.6.2.2	Chemical oxygen demand - closed reflux titrimetric method	274
8.6.3	Fat and fibre	278
8.6.3.1	Crude fat - Soxhlet extraction method	278
8.6.3.2	Crude fibre - filtration method	282
8.6.4	Nitrogen	286
8.6.4.1	Total nitrogen - spectrophotometric method	287
8.6.4.2	Ammonium - colorimetric (test strip) method	290
8.6.4.3	Ammonium - phenate spectrophotometric method	292
8.6.4.4	Ammonia - distillation and titration method	295
8.6.4.5	Nitrite - colorimetric (test strip method)	299
8.6.4.6	Nitrite - spectrophotometric method	301
8.6.4.7	Nitrate - colorimetric (test strip method)	303
8.6.4.8	Nitrate - cadmium reduction spectrophotometric method	305
8.6.4.9	Total Kjeldahl nitrogen - distillation and titration method	308
8.6.5	Phosphorus	312
8.6.5.1	Total phosphorus and orthophosphate - spectrophotometric method	312
8.6.5.2	Orthophosphate - colorimetric (test strip) method	316
8.6.6	pH and electrical conductivity	318
8.6.6.1	pH - electrode method	319
8.6.6.2	Electrical conductivity - electrode method	322
8.6.7	Elemental analysis	324
8.6.7.1	Metals - overview	324
8.6.7.2	Metals - acid digestion for environmentally available metals	325
8.6.7.3	Ultimate analysis - total carbon, hydrogen, nitrogen, oxygen, and sulphur	328
8.6.7.4	Chlorine - colorimetric (test strip) method	331
8.6.7.5	Chlorine - spectrophotometric method	332
8.6.7.6	Chloride - colorimetric (test strip) method	334
8.6.7.7	Chloride - spectrophotometric method	336
8.6.8	Colour and turbidity	338
8.6.8.1	Colour - visual comparison method	339
8.6.8.2	Turbidity - nephelometric method	341
8.6.9	Settleability and dewaterability	344
8.6.9.1	Jar test	344
8.6.9.2	Capillary suction time	346
8.6.9.3	Water activity	348
8.6.9.4	Sludge volume index	351
8.7	Physical properties	352
8.7.1	Physical and mechanical properties	352
8.7.1.1	Density - mass and volume measurement method	353
8.7.1.2	Density - volume displacement method	354

8.7.1.3 Particle size - laser light scattering method	356
8.7.1.4 Rheological properties - rheometer method	360
8.7.1.5 Liquid limit - cone penetrometer method	362
8.7.1.6 Plastic limit - thread-rolling method	364
8.7.1.7 Compressibility and stickiness - texture analyser method	366
8.7.2 Physical and thermal properties	368
8.7.2.1 Thermal conductivity - thermal conductivity analyser method	368
8.7.2.2 Calorific value - bomb calorimeter method	370
8.8 Biological properties	373
8.8.1 Pathogens	373
8.8.1.1 <i>E. coli</i> and total coliforms - colony forming unit method	374
8.8.1.2 <i>E. coli</i> , faecal coliforms, and total coliforms - the most probable number method	378
8.8.1.3 Bacteriophage - plaque assay method	383
8.8.1.4 Helminth - microscopy method	386