TRACE STUDY OF WATER PHDs IN SOUTH AFRICA

Report to the
Water Research Commission

by

Prof Anastassios Pouris[1] and Dr George Thopil[2]
[1]Quantitative Evidence Research
[2]University of Pretoria

WRC Report No. 2851/1/20
ISBN 978-0-6392-0153-5

June 2020

Obtainable from

Water Research Commission

Private Bag X03

GEZINA, 0031

orders@wrc.org.za or download from www.wrc.org.za

EXECUTIVE SUMMARY

This document reports the employment findings of a tracer investigation of Water and Sanitation-related Doctoral degrees awarded during the period 2013-2017 from South African universities. This is the first investigation of this nature in the fields of water and sanitation in South Africa and probably internationally. Tracer surveys – also known as graduate destination surveys or alumni surveys – are undertaken internationally informing policy authorities of the characteristics and opinions of PhD graduates.

The objectives of the investigation were as follows:

- Do we train too many or too few water-related PhDs?
- How mobile are doctorate-holders between sectors?
- When do doctorate-holders leave research for a career in management?
- Are water-related PhDs remaining in the country?
- Can we trace the work experience of water-related PhDs?

Furthermore, the findings of the investigation can express an opinion related to the appropriateness of current targets in the RDI Water Roadmap (2015).

The main challenge is in identifying PhDs in the field of water and sanitation since universities do not offer explicitly PhDs related to water. For this investigation PhDs with qualifications related to Water and Sanitation were identified. The National Electronic Theses and Dissertations (NETD) and NEXUS databases were utilised in identifying doctoral awardees whose theses' titles and/or abstracts contained relevant keywords. The identified theses were then examined for "precision", and 112 theses relevant to the scope of the investigation were identified.

The websites of relevant universities; databases indexing academic articles; and social media were examined in order to identify the relevant characteristics of the doctoral graduates. A questionnaire was developed and was sent to the identified PhDs. The used methodology has been successful in identifying the employment characteristics of all PhDs. It is emphasised that tracers studies in South Africa suffer from either small samples or low percentage of response rates.

The main findings are as follows:

- All PhD-holders were engaged in jobs. Out of the sample of 112, 107 profiles were very traceable. Specifically, employment profiles were traceable for 104 graduates, all of who were found to be employed. Statistically all population is employed.
- More than 50% of the PhD-holders occupied positions in the university sector. Of those in the university sector roughly 23% held post-doctoral positions.
- Approximately 30% of the PhD-holders were in other African countries having gone back to their country of origin. This is an important policy issue of concern to the Department of Higher Education and Training (DHET), Department of Science and Innovation (DSI) and Department of International Relations and Cooperation (DIRCO).

- Approximately 90% of the respondents were in occupations related to the Water and Sanitation sector. While this finding does not confirm the claim of the *Water RDI Roadmap* that the system requires 200 PhD per year it makes apparent that under current market conditions PhDs can identify jobs and their expertise is needed. An interesting question is why the local universities do not employ the foreign PhD graduates who return back to their country of origin.
- Mobility between sectors was identified to be 16%. Eighteen out of 112 graduates identified to have transitioned between sectors.
- The work experience of 40.1% of the PhD holders was identified to be between 2 to 5 years.
- Twenty PhDs (18%) declared that they had management experience.

The authors suggest that the results indicate a high demand for PhDs in the field of Water and Sanitation, although it is not clear whether the demand is for PhD graduates from all disciplines and that the same phenomenon will be apparent in other scientific disciplines.

The following recommendations are made:

It is important to investigate whether the identified results are unique in the water sector or they apply across the board in other sectors as well. It is suggested that a similar investigation covering the majority of broad scientific sectors in South Africa should be undertaken. Such an investigation will inform the National Development Plan which suggest the production of 5000 PhDs per annum.

The large number of PhDs returning to their countries is also an issue requiring further investigation. Foreign students assist universities to export their services. Student living expenses, expenses from visiting family members and friends are among the tangible benefits to the country. The university expenses related to particular PhD candidate is the relevant costs. In South Africa there are no relevant estimates to guide policy. Furthermore the numbers of PhDs remaining in the country are substantially lower than previous estimates raising issues of supporting the local demand.

Finally, it is suggested that this type of investigation should be repeated including the expanded population every two years so there is continuity with the responding PhDs and that the relevant results be included in the South African Water Research Indicators of the WRC.

ACKNOWLEDGEMENTS

The project team wishes to thank the following people for their contributions to the project.

Reference Group	**Affiliation**
J Dini	Water Research Commission
S Nienaber	Water Research Commission
M Mabizela	Department of Higher Education and Training
B Hadebe	Department of Science and Innovation
V Malele	Department of Science and Innovation
B Mchunu	Department of Science and Innovation
N Hanke-Louw	ESETA
K Masilo	ESETA
G Gericke	Eskom
S Manzini	Green Matter
JC Diedericks	National Research Foundation
A Pouris	National Research Foundation
P Shisani	National Research Foundation
J Tempelhoff	North-West University
B Marais	S&T Network
M Jackson	Stellenbosch University
J Mouton	Stellenbosch University
D Naidoo	Umgeni Water
M Thopil	University of Pretoria
Others	
J Dini	Water Research Commission for constructive criticisms
A Thirion	QERcc Research support
T Molefe	University of Pretoria Research support
M Thopil	University of Pretoria Research support

This page was intentionally left blank

CONTENTS

EXECUTIVE SUMMARY iii
ACKNOWLEDGEMENTS v
CONTENTS vii
LIST OF FIGURES vii
ABBREVIATIONS viii
INTRODUCTION 1
LITERATURE REVIEW 3
METHODOLOGY 7
FINDINGS 9
Demographic Characteristics 9
Sector-based Distribution 11
Work Experience Profile 13
Retention of PhD Graduates Within the Water Sector 14
DISCUSSION AND RECOMMENDATIONS 16
REFERENCES 19
APPENDIX 1: Key-words Utilised for the Identification of PhD-holders 21
APPENDIX 2: Questionnaire 22

LIST OF FIGURES

Figure 1: Demographic characteristics of tracer cohort 10
Figure 2: Nationality of tracer cohort (respondents) 10
Figure 3: Current location of tracer cohort 11
Figure 4: Sectoral breakdown of current employment profile 11
Figure 5: Gender and racial composition of current employment profile 12
Figure 6: Sectoral breakdown of previous employment profile 13
Figure 7: Proportion of graduates who are mobile between sectors 13
Figure 8: Years of experience in current role 14
Figure 9: Proportion of graduates with managerial experience 14
Figure 10: Breakdown of opinions related to need for water sector PhDs 15

ABBREVIATIONS

Abbreviation	Name
AGS	Australian Graduate Survey
ASSAf	Academy of Sciences of South Africa
BGS	Beyond Graduation Survey
CEQ	Course Experience Questionnaire
CHEC	Cape Higher Education Consortium
DAAD	Deutscher Akademischer Austrausch Dienst (German Academic Exchange Service)
DHET	Department of Higher Education and Training, Science and Technology
DIRCO	Department of International Relations and Cooperation
DPRU	Development Policy Research Unit
DSI	Department of Science and Innovation
ESF	European Science Foundation
EU	European Union
GCA	Graduate Careers Australia
GDS	Graduate Destination Survey
GHS	General Household Survey
GSS	Good Skills Scale
GTS	Good Teaching Scale
HEI	Higher Education Institutions
HESA	Higher Education South Africa
HRST	Human Resources for S&T
LIS	Library and Information Services
MEd	Masters in Education
NASA	National Aeronautics and Space Administration
NEH	National Endowment for the Humanities
NETD	National Electronic Theses and Dissertations Database
NIH	National Institutes of Health
NRF	National Research Foundation
NSF	National Science Foundation
OECD	Organisation for Economic Cooperation and Development
PREQ	Postgraduate Research Experience Questionnaire
QLFS	Quarterly Labour Force Survey
RDI	Research, Development and Innovation
S&E	Science and Engineering
S&T	Science and Technology
SAQA	South African Qualifications Authority
SED	Survey of Earned Doctorates
US(A)	United States (of America)
USDA	US Department of Agriculture
WRC	Water Research Commission

INTRODUCTION

The training of doctoral graduates as well as researchers is a long and costly endeavour and is regarded as essential in a knowledge-based and complex economy. Doctoral graduates are considered the best qualified for creating, implementing and disseminating new knowledge and innovation.

The Organisation for Economic Co-operation and Development (OECD) and the Statistical Office of the European Union (EU), Eurostat, have as early as 1995 released a *Manual on the Measurement of Human Resources Devoted to Science and Technology* (HRST), otherwise known as the *Canberra Manual* OECD/Eurostat (1995). This Manual gives guidelines on the measurement of stocks and flows of HRST along various dimensions as well as on the data sources to be used. The number of PhDs is one of the recommended variables/indicators.

More recently, OECD/UNESCO (2007) together with the UNESCO Institute for Statistics and Eurostat, launched a project aimed at measuring the labour market outcome, career path and mobility of this highly qualified population. PhD unemployment in Portugal and Australia was 2.5% and 2.3% respectively which was half the unemployment in the general population

Currently a number of countries (e.g. Australia; China; US) monitor their PhDs after graduation by undertaking regular surveys. The surveys aim to answer questions related to international mobility (brain gain, brain drain, brain circulation); issues of qualitative and quantitative adequacy of the education of doctorate holders for the labour market; how well the skills of the highest educated are used as well as the attractiveness of different career paths to doctorate holders and similar.

OECD (2010 p 13) suggested that these surveys can address the following issues which bear policy implications:

- "The role of doctorate-holders in innovation and the knowledge economy

  Where do doctorate holders work as compared to other tertiary graduates? Do they follow research careers and in what sector and field?

- Labour market supply and demand

  Do we train too many or too few doctorate-holders? Are there mismatches in the labour market? Why do doctorate-holders choose a research career in the public sector, or in the private sector or leave research? What is their perception of career opportunities and employment situation in the public versus the private sector? Do they earn more than the average citizen and which sectors of employment are the most profitable?

- Education to work

  How long is the time of transition to employment or post-doctoral experience? How related is the job to the doctoral degree?

- Mobility

  How mobile are doctorate-holders between sectors? When do doctorate-holders leave research for a career in management? How big are the flows of doctorate-holders between countries? How common it is for doctorate-holders to reside in a country on a non-permanent basis? What are the reasons for doctorate-holders to return to their country of origin?"

The findings of these efforts are vital for educational planners within the Government and in academia. The results are also used by employers in all sectors (education, industry, and the government) to understand and predict trends in employment opportunities and salaries in Science and Engineering (S&E) fields for doctorate holders and to evaluate the effectiveness of equal opportunity efforts. Research agencies also find the results important for internal planning as their grants go usually to individuals with doctoral degrees. This information is not monitored in South Africa.

The objectives of this investigation are related to PhDs with theses related to Water and Sanitation and are as follows:

- Can we trace the work experience of water-related PhDs?
- Do we train too many or too few water-related PhDs?
- How mobile are doctorate-holders between sectors?
- When do doctorate-holders leave research for a career in management?
- Are water-related PhDs remaining in the country?

Furthermore, the findings of the investigation express an opinion related to the appropriateness of current targets in the RDI Water Roadmap WRC/DST (2015) and provide recommendations for revision of targets and choice of indicators as necessary.

The recent Investigation related to *Mapping Water RDI Ecosystem* (Pouris, 2018:9) states: "The number of Doctorates produced per year varies from 15 to 30 per year. These figures are below the 200 Doctorates per year expected in the Roadmap. However, it is emphasised that this is a much better performance from what is expected from the funding of R&D in the country. Water R&D expenditures constitute just below 1% of the country's total expenditure. Hence, the expected number of Doctorates was supposed to be 1% of the 1 263 that graduated in all disciplines during 2015. The actual number however, is almost three times the expected one. It is apparent that the human resources produced, related to water, are more than what was expected from the relevant inputs".

The current investigation examined whether the produced PhDs are utilised in the field of Water and/or Water Research. If water-related PhDs are not utilised in their field of expertise, it may be argued that the labour market does not necessarily require them. It is emphasised that the issue is more complex than what it appears. PhD-holders may move to other research areas but they could easily be re-engaged in the original field of their studies depending on the market needs.

LITERATURE REVIEW

The term tracer surveys, also known as graduate destination surveys or alumni surveys, are undertaken internationally from China (Yue, 2014) to Australia (QILT, 2018) and the USA (NSF, 2018). Tracer surveys have a long history. In Australia the Australian Graduate Survey (AGS) was piloted in 1972 and has been conducted annually by Graduate Careers Australia (GCA) and higher education institutions since 1974, with Federal and institutional funding and support. Prior to 2006, it was known simply as the Graduate Destination Survey. The name Australian Graduate Survey was adopted in 2006 to act as an umbrella project title for the Graduate Careers Australia's combined Graduate Destination Survey (GDS), Course Experience Questionnaire (CEQ) and the Postgraduate Research Experience Questionnaire (PREQ) work.

The GDS essentially collects data regarding the immediate (four months) post-study activities of new graduates. The collected information includes full- and part-time employment and labour market activity, further study, job search methods, and the relationship between employment and higher education qualifications. The GDS is now complemented by the Beyond Graduation Survey (BGS) which is a three- and five-years after follow up.

The CEQ collects data regarding the views and comments of new graduates concerning their experience of study at the institution. It consists of two core scales – Good Teaching (GTS) and Generic Skills (GSS) – of the GDS.

The RREQ collects data regarding the views and comments from students who recently graduated from their research Masters or Doctoral degrees, concerning their experience of research at the institution. Respondents are asked to express their degree of agreement or disagreement on statements (items) using a five-point Likert scale. The PREQ topics covered are as follows:

1. Supervision Scale (6 items)
2. Intellectual Climate Scale(5 items)
3. Skills Development Scale (5 items)
4. Infrastructure Scale (5 items)
5. Thesis Examination Process Scale (3 items)
6. Clarity of Goals and Expectations Scale (3 items)
7. Overall Satisfaction Scale (1 item)

In the USA the Survey of Earned Doctorates (SED) is an annual census of individuals, since 1957, who receive research doctoral degrees from accredited US academic institutions (NSF, 2018). The survey is sponsored by six federal agencies: National Science Foundation (NSF), National Institutes of Health (NIH), the US Department of Education; National Endowment for the Humanities (NEH); US Department of Agriculture (USDA), and National Aeronautics and Space Administration (NASA).

The SED collects annually census information on the doctoral recipients' educational history, demographic characteristics, and post-graduation plans. Results are used to assess characteristics of the doctoral population and trends in doctoral education and degrees.

These data are reported in several publications from NSF's National Center for Science and Engineering Statistics. The most comprehensive and widely cited publication is the annual report, *Doctorate Recipients from US Universities*.

Institutional coordinators at each doctorate awarding institution distribute the SED Web survey link (or paper survey form) to individuals receiving a research doctorate.

In 2016, 92% of research doctorate recipients completed the survey instrument. A number of records (field of study, doctoral institution, and sex) are constructed for non-respondents from administrative records of the university – commencement programs, graduation lists, and other public records – and are included in the reported total of doctorate recipients.

Key variables of interest are listed below.

- Academic institution of doctorate
- Baccalaureate-origin institution (U.S. and foreign)
- Birth year
- Citizenship status at graduation
- Country of birth and citizenship
- Disability status
- Educational attainment of parents
- Educational history in college
- Field of each degree earned (*N* = 331 fields)
- Graduate and undergraduate educational debt
- Marital status, as well as the number and age of dependents
- Post-graduation plans (e.g. work, post-doc, other study or training)
    - Primary and secondary work activities
    - Source and type of financial support for post-doctoral study or research
    - Type and location of employer
    - Basic annual salary
    - Race and ethnicity
    - Sex
    - Sources of financial support during graduate school
    - Type of academic institution (e.g. historically black colleges and universities, Carnegie codes, public or private) awarding the doctorate

Unemployment rates in the USA among the doctorate holders are low (2.4%). However it should be emphasised that the disciplinary makeup of the doctorate holders (emphasis on biological sciences and engineering) is different than in South Africa (emphasis on Social sciences).

In Europe ESF-Science Connect (2017), together with eight European universities and research performing organisations, launched its second career tracking survey of doctorate holders. The survey, focusing on doctoral graduates of the years 2010 to 2016, was launched in March 2017 and collected over 2 000 responses, with the response rate of 23%.

The aims were to enable participating organisations to better understand the occupational and mobility patterns as well as satisfaction levels of their doctorate graduates. Participants collected this data for their own monitoring and planning purposes with the intention of improving their doctoral education and career advice

The ESF, together with its experts and partner organisations, designed an online questionnaire to collect anonymised data on doctorate-holders up to seven years after PhD completion. The questionnaire had a core part, common to all organisations, as well as additional organisation-specific modules developed together with the participating organisations. The project required availability of contact data for doctorate-holders within participating organisations. Relevant demographic, career mobility and social and economic outcome data of the doctorate-holders, including skills utilisation patterns and transfers, was collected. The deliverables provided to each participant organisations included individual reports (with a statistical analysis and an anonymised data set) and a global final report.

The main findings from the ESF-Science Connect (2017) report are as follows:

- “A very high employment rate of doctorate holders (95%)
- A vast majority (80%) are working as researchers
- The overall unemployment rate (4%) diminishing over time
- 60% of the respondents currently working in the academic field
- Only 50% of those working in universities are permanently employed compared to the majority of those working in industry
- While the majority of positions in universities/research organisations require a doctorate, or even a post-doctorate qualification, a master’s-level degree is most required for those in government, services or hospitals.
- In industry, equally large shares of respondents (45% each) worked in positions that require a doctorate or a master’s-level degree
- Male doctorate holders prevail in natural sciences, engineering and agricultural sciences, and women in medical and health sciences, social sciences and humanities
- Similarly high shares of men and women work as researchers, and similar proportions of men and women work in senior academic posts and other position levels
- High levels of geographic mobility with 40% having lived in a foreign country for more than three months after graduation, mostly within Europe and North America
- Nearly 60% of researchers involved in trans-national cooperation, while lower levels of cross-sectoral collaboration”

In ten tracer studies (conducted in 1996-1997) of transitions from higher education to work in six African countries, Mugabushaka *et al.* (2003) found that unemployment rates varied from 5% (for cohorts who graduated in the 1980s) to 10% (for cohorts who graduated in the mid-1990s), and that 73% of those surveyed were employed in the public sector. The investigation was focused on the mismatch between graduate skills and labour needs.

A limited number of tracer studies have been undertaken in South Africa. The investigations covered graduates from particular institutions and particular disciplines (e.g. Shongwe *et al.,* 2011 covering graduates of the Department of Library and Information Sciences from the University of Zululand); quality of the graduates and the relevance of the skills of the graduates (Griesel *et al.,* 2009 covering employers of undergraduates); undergraduates and postgraduates across the board (Van den Berg *et al.,* 2012 investigating unemployment levels with household surveys data) and others. A report by the Academy of Science of South Africa (ASSAf, 2010) describes the challenges of such exercises. The stated challenge was that the South African Qualifications Authority (SAQA) did not have e-mail addresses; eventually they were forced to ask individual universities to send the questionnaires to their PhDs and request them to respond. Such an approach had its own shortcomings. Universities did not send e-mails only to those who had graduated recently (10 years) and hence, the population could not be estimated. In general, there were delays in delivering in the total effort.

In reviewing the relevant literature in South Africa, Botha (2015) identified that the main objective of the various investigations was focused on information on the employment of masters and doctoral graduates. An important finding is that "There is a need for a major research database in South Africa from which not only national graduate samples can be drawn, but also information on the transition from university to work" (p8).

The responses of the South African investigations range from relatively small numbers, i.e. 11 graduates (Singh, 2010); 50 respondents (Shongwe *et al.,* 2011, Blassoples, 2011) and 100 respondents (Griesel *et al*., 2008) to a few thousand.

The investigations with large number of participants have response rates ranging from 4% (Mouton, 1998) to 22% (Kraak, 2010). A Cape Higher Education Consortium (CHEC) (2013) study targeted a response rate of 33%. The achieved rate was 23%.

Botha (2015) argues that the studies by Kraak (2010), Bhorat (2004) and the Development Policy Research Unit (DPRU, 2006) – based on surveys of graduates – report levels of graduate unemployment almost twice as high as those in the studies of Van den Berg *et al*. (2012) and Van Broekhuizen (2013). The latter were based on a secondary data analysis of standards reports of Statistics South Africa, such as the Quarterly Labour Force Survey (QLFS) (cf. Statistics South Africa, 2008) and the General Household Survey (GHS) (cf. Statistics South Africa, 2013).

For example, Van den Berg *et al.* (2012) identified that graduate unemployment in South Africa (where 'graduates' are considered to be those with at least a university degree) was low in an international context. The broad graduate unemployment rate was below 5% (2010), below the more than 8% of 2001.The unemployment rates for graduates in the other studies was above 10%.

It should be emphasised that a number of the reviewed investigations were not published documents.

The recent ASSAf (2018:18) report states that "There was a general view that postgraduate training was not essential in the workplace and that persons with a first degree were more affordable to a company, although it was recognised that engineers with a postgraduate qualification have better lateral thinking

skills". The report identified key fields where the demand for engineers is likely to increase. The field of "water" was on top of the list. There were not available statistics for PhD graduating in the field of Water.

METHODOLOGY

The methodological steps for this effort involved the following:

1. Literature review. The review covered local and international relevant literature and is outlined in the earlier section of the report.
2. Identification of the names and titles of thesis of postgraduate students completing their PhD in the period under examination (target population) including supervisor and university. The most recent 5 year period (2013-2017) was chosen. The use of a ten year period was debated but low response rates from previous investigations indicated that a 5-year period would improve the response rate. The methodology developed in Pouris (2018) was used for this step. Water research is a multidisciplinary field. Students undertake their PhD theses in a variety of Departments (e.g. microbiology, natural sciences, geosciences, etc.). Hence, it was decided to identify PhD theses through their titles. The challenges related to searches through key words (Appendix 1) that were identified in Pouris (2018) are the concepts of recall and precision. In information retrieval, a perfect precision score means that every result retrieved by a search was relevant (but says nothing about whether all relevant documents were retrieved) whereas a perfect recall score means that all relevant documents were retrieved by the search (but says nothing about how many irrelevant documents were also retrieved). In order to manage these challenges, the titles and abstracts of the theses identified by the key words were examined manually for inclusion in the relevant set. The NEXUS database of the NRF and the NETD portal were used for the identification of the relevant PhDs. The two systems are planned to be merged into one portal in order to enhance their usefulness and provide a single searchable and comprehensive research database (NRF, 2017).
3. Identification of the contact details of the target population. In tracing studies such as this one, personal information including addresses, e-mails and telephone numbers and so on are usually collected from universities' alumni offices. These offices keep reasonably complete records of the graduates of their institutions. A formal approach is usually followed by informing the Principals of the universities of the effort and requesting their participation. For this investigation we didn't need to approach the universities as all relevant information was identified in the social media; publicly available databases and similar. All relevant contact particulars were identified.
4. Development of questionnaire. Based on international experience and best-practice (literature review) and the aims of this investigation, a questionnaire was developed and it was tested with a few stakeholders for validity. Following international best-practice, the questionnaire was divided into six different modules dealing with different aspects of issues of interest of doctorate-holders:
    - doctoral education,
    - early career research positions,
    - employment situation,
    - international mobility,
    - career-related experience and

- personal characteristics.

It should be emphasised that long questionnaires will limit the response rate. Hence, we attempted to balance the number of questions to be included with the desirable response rate. It should be emphasised that the target for this investigation was to have a high response rate.

5. Survey of the target population (doctorates graduated the most recent five years). A census approach was followed. A multitude of approaches were planned to be followed (e.g. reminders; telephonic and personal interviews, etc.) in order to improve response rates.
6. Three rounds of emails with the questionnaire (Appendix 2) was sent out to the 100 identified respondents with the first round being sent in November 2018, and follow up emails sent out in February 2019 and April 2019. Telephonic reminders were also made based on non-responses. In a number of cases identified telephone numbers were not valid anymore which limited telephonic follow ups.
7. The results were analysed in order to provide answers to the objectives of the investigation.

FINDINGS

As we already mentioned, the process of identifying water-related PhDs awarded during the 2013-17 period started by identifying in the NETD and NEXUS databases the theses with relevant keywords in the title and/or the abstract. The keywords used in the search are listed in Appendix 1. The identified theses (approximately 300 of the 12 500 total theses for the 5-year period) were examined for "precision" and ended up 112 relevant theses. A thesis was excluded if its topic, although including one or more of the relevant terms, could not inform any of the issues mentioned in the Water RDI Roadmap (WRC/DST, 2015). For example the topic "Messages from the deep: water divinities, dreams and diviners in Southern Africa" was excluded. The websites of relevant universities; databases indexing academic articles and social media were investigated in order to identify the relevant characteristics of the authors of these theses. From the 112 identified relevant theses, contact details (in the form of either email addresses or phone numbers) were obtained for 100 doctorate graduates. In five cases out of the 112, the profiles were not traceable. For seven PhDs graduates limited information (about employment, residence, etc.) was traceable but phones numbers or e-mails were not traceable. Accordingly, questionnaires were sent out to 100 doctorate graduates out of which 48 individuals returned completed questionnaires.

Demographic Characteristics

The first section of the questionnaire aimed to identify the demographic characteristics of the 112 PhD graduates. The demographic characteristics included identifying the gender and racial constitution of the cohort (Figure 1: Demographic characteristics of tracer cohort.

The number of male graduates was almost double (63.4%) compared to the female graduates (32.1%). A similarly skewed gender distribution can also be seen within the predominant racial categories.

Figure 1: *Demographic characteristics of tracer cohort*

Nationality information (Figure 2) was obtained for a number of PhD-holders based on the willingness of the individuals within the group, to respond to the specific query.

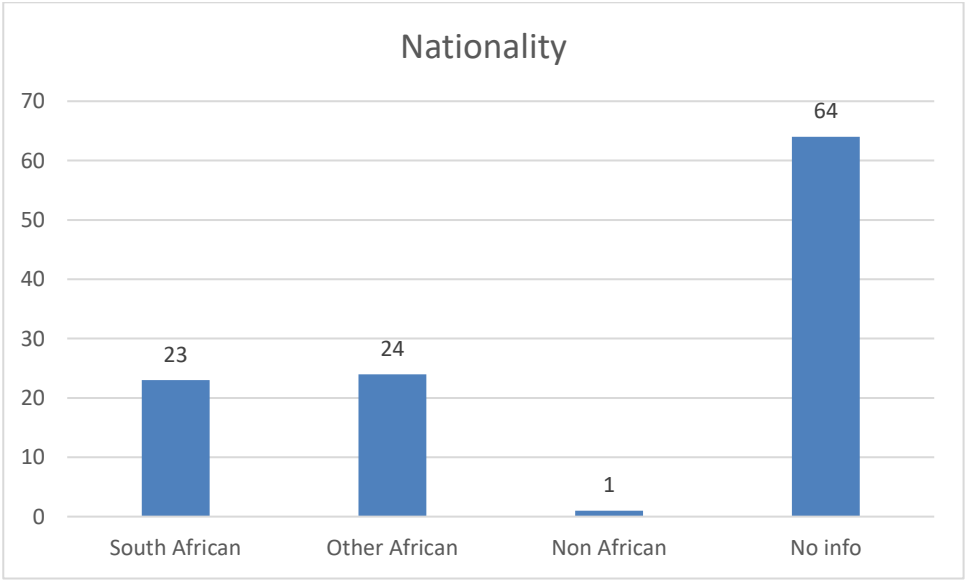

Figure 2: *Nationality of tracer cohort (respondents)*

The majority (62.5%) of the PhD graduates are still located within South Africa with the over whelming majority (87.5%) being within Africa. Figure 3 provides a breakdown of the current location of the graduates.

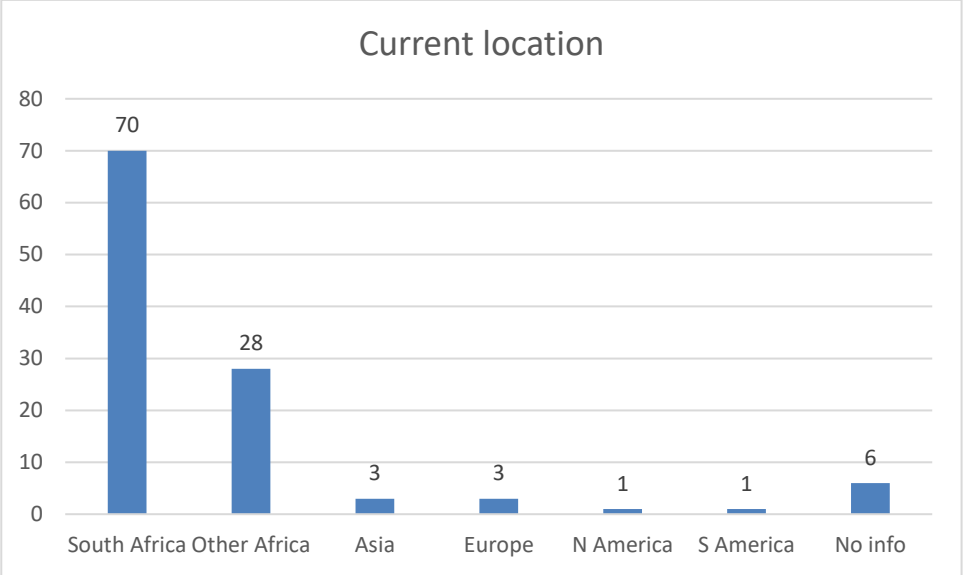

Figure 3: *Current location of tracer cohort*

Sector-based Distribution

The second section of the questionnaire aimed to identify the current position of the graduates. It can be seen (in Figure 4) that the majority of the graduates are within the academic sector with representation within the other sectors as well. It is important to be noted that all graduates were employed. Another worthwhile point of note within the largest category, i.e. academia, is that 13 out of 57 (23%) of the PhD-holders were identified to be post-doctoral fellows or post-doctoral researchers. It can be expected that post-doctoral fellows and researchers will be absorbed in the labour market after their contracts expire, as there is no current evidence of individuals who have previously completed post-docs and are currently unemployed.

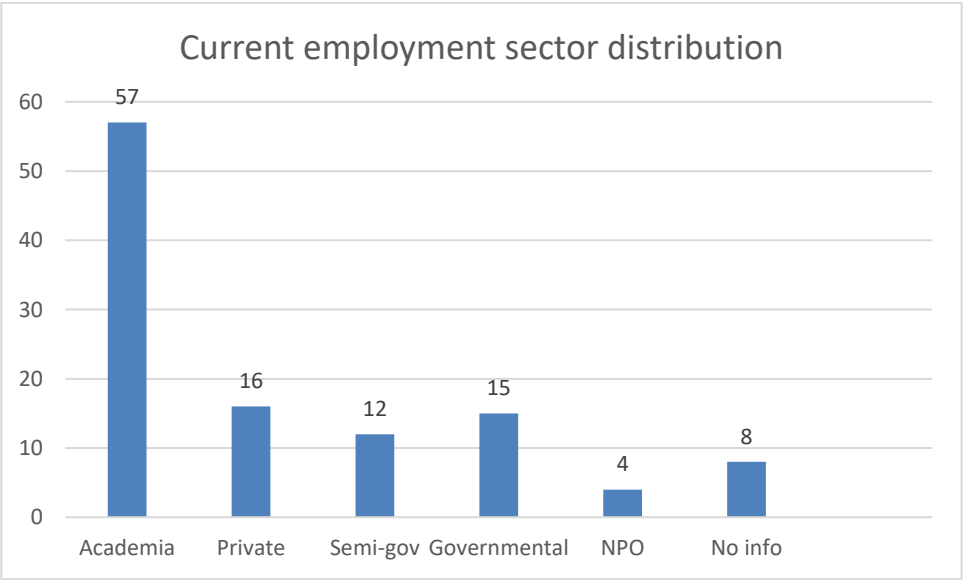

Figure 4: *Sectoral breakdown of current employment profile*

Figure *5* provides a breakdown of the gender and racial composition of the cohort's current employment. The main four categories (i.e. academia, private, semi-government and governmental are broken down according to gender and race. The semi-government category consisted of science councils and research institutes affiliated to the government whereas NPOs included not for profit organisations that did not have governmental stake holding. It is worthwhile to note that a 2:1 gender ratio exists across all main categories. Within the NPO category (total of 4) an equal gender distribution was noted with two males and two females. The racial distribution consisted of two white males and one black female and one white male. The NPO category is not represented graphically because of the small size of the category.

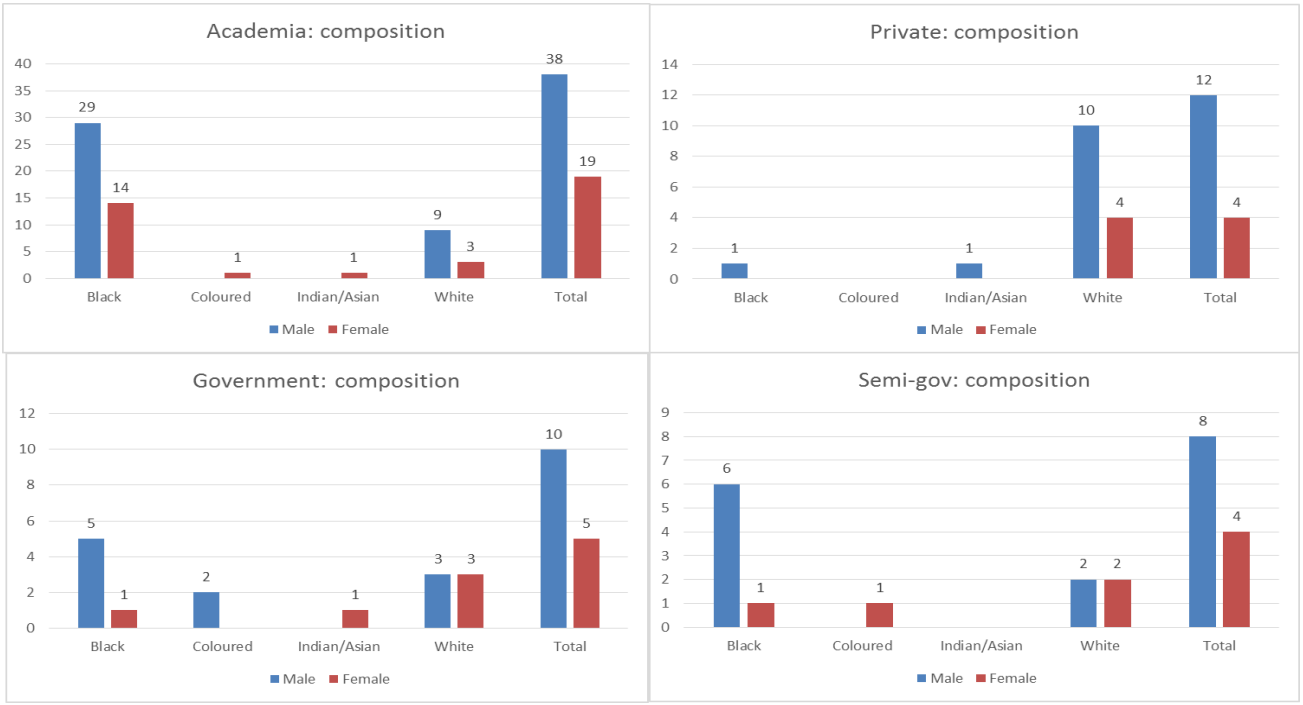

Figure 5: *Gender and racial composition of current employment profile*

When identifying most relevant previous experience a similar profile amongst the sectors was seen (in **Figure *6***). A number of the graduates were identified to have no prior experience as a result of being in their first employment after completing full-time studies.

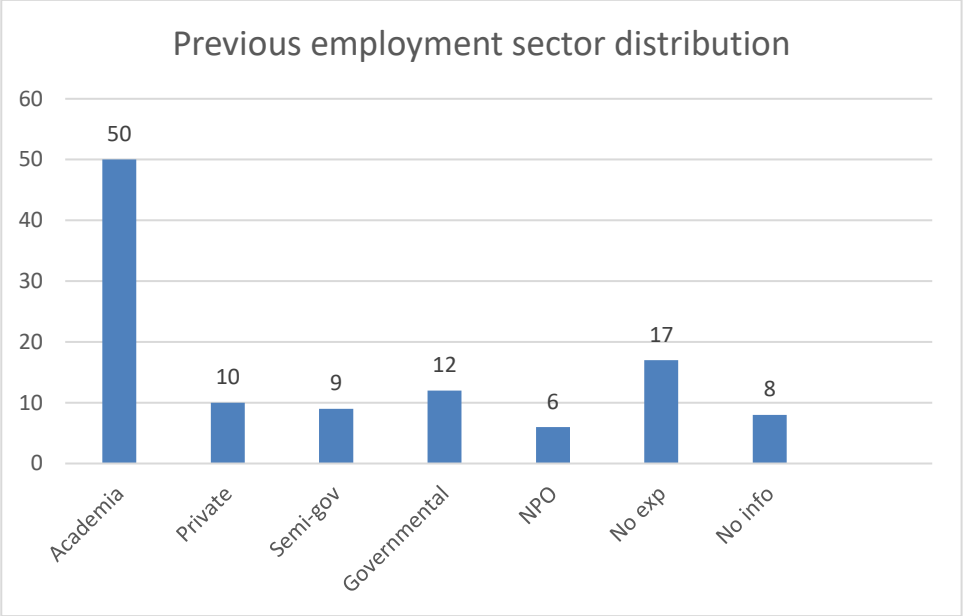

Figure 6: *Sectoral breakdown of previous employment profile*

Mobility between sectors/categories was identified to be limited (**Figure *7***), with 16% (i.e. 18 out of 112) of the graduates identified to have transitioned between sectors. The majority of the graduates continued in the same sector when taking into account that full time students with no experience in Figure 6 were considered to be part of academia.

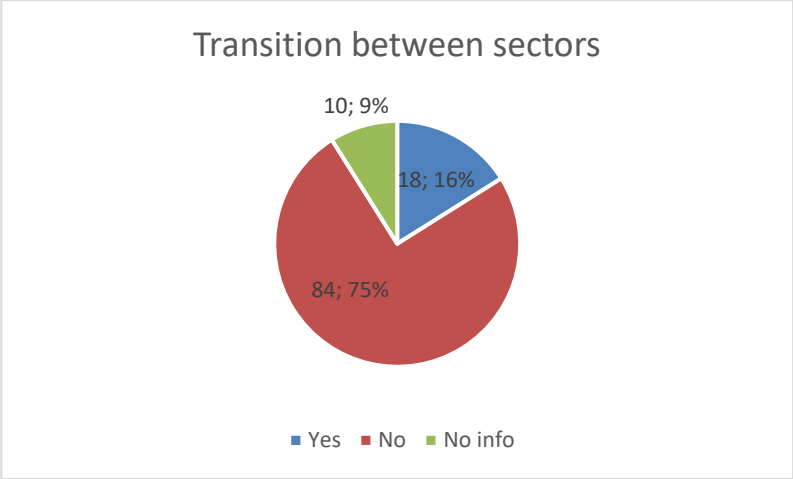

Figure 7: *Proportion of graduates who are mobile between sectors*

Work Experience Profile

An analysis of the experience profile of the graduates indicated the majority (40.1%) of the graduates to have experience between 2-5 years (**Figure *8***). Such an observation is in line with the expected profile, considering the period (2013-2017) of the study.

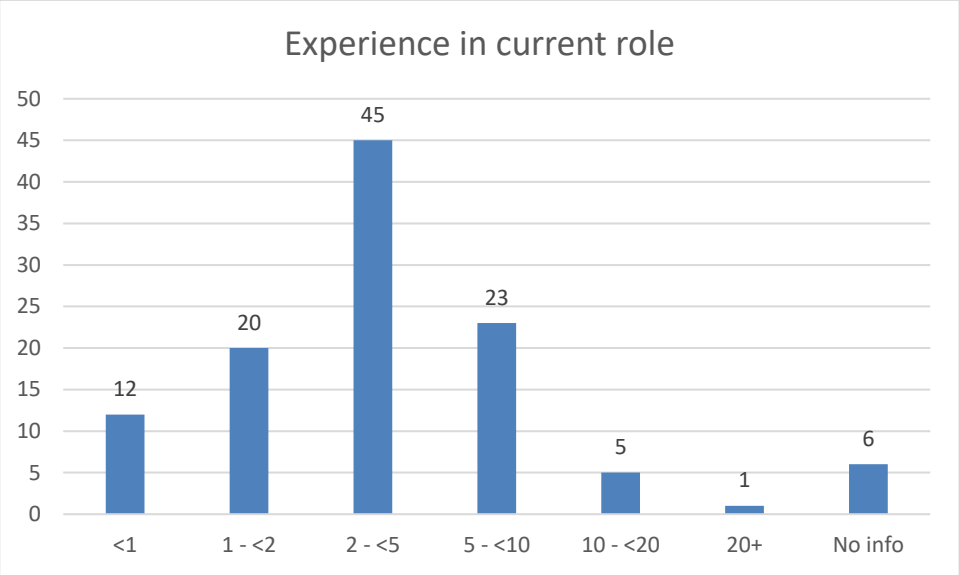

Figure 8: *Years of experience in current role*

It was also seen that roughly 20% (i.e. 18 out of 112) of the group has managerial experience (**Figure *9***).

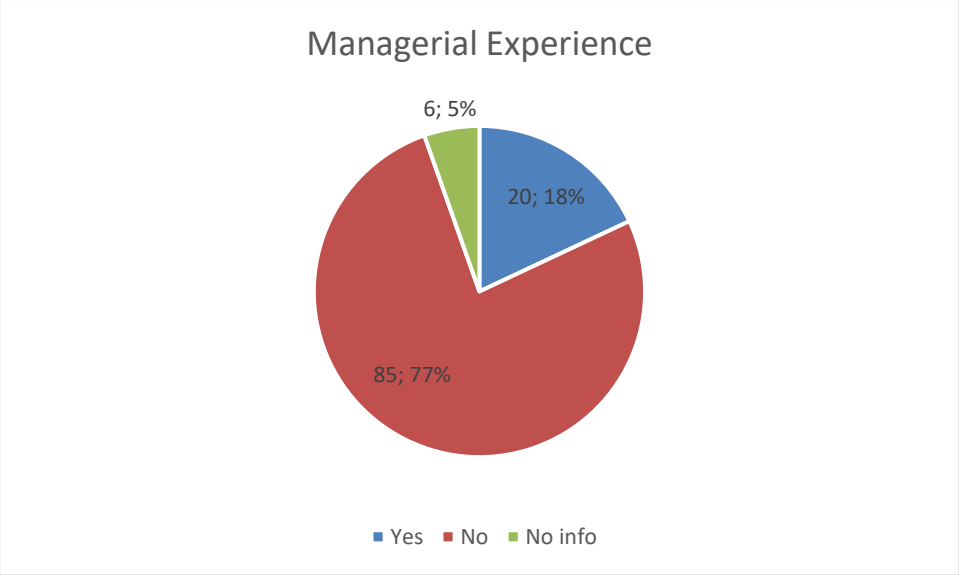

Figure 9: *Proportion of graduates with managerial experience*

Retention of PhD Graduates within the Water Sector

The latter sections of section C of the questionnaire attempted to gauge the continued linkage of the respondents with the research undertaken during their PhD and their continued participation within the water sector. Five out of 48 graduates who responded to the question regarding continuity in the water sector indicated that they were not working in the sector anymore. This indicates that the water sector manages to retain approximately 90% of the PhD graduates. Some of the comments linked to reasons for moving to other sectors of work are noted in Box 1. It was also noted that all PhD graduates were employed. A high number of graduates (90%) were able to generate scientific outputs in the form of journals, patents, book chapters, etc., with a pilot plant being demonstrated in one case.

Comment 1: Working as a pharmacist prior to pursuing a PhD. Current work links to public health.

Comment 2: Pursue new research areas in chemistry. Lack of facilities in current institution to continue research in PhD-related research.

Comment 3: Working in mammalian cognition. Had to take up available opportunity due to lack of opportunities in PhD-related work.

Comment 4: Preferred not to continue in the sector due to factors related to reduced funding.

Comment 5: Took up an opportunity that was available after emigration.

Box 1. *Comments related to moving from the water sector*

In order to gauge the state and need of PhD retention within the Water sector, the questionnaire (section D) attempted to query the opinion of the participants, on if there was an abundance of PhD graduates in the water sector. If participants agreed that there was an abundance, they were asked how the sector could absorb these graduates. If participants were of the opinion that there was a deficit in PhD graduates, they were asked to identify roles within their organisation in which PhD graduates were required for. **Figure *10*** provides an indication of the feedback in 48 responses received for section D.

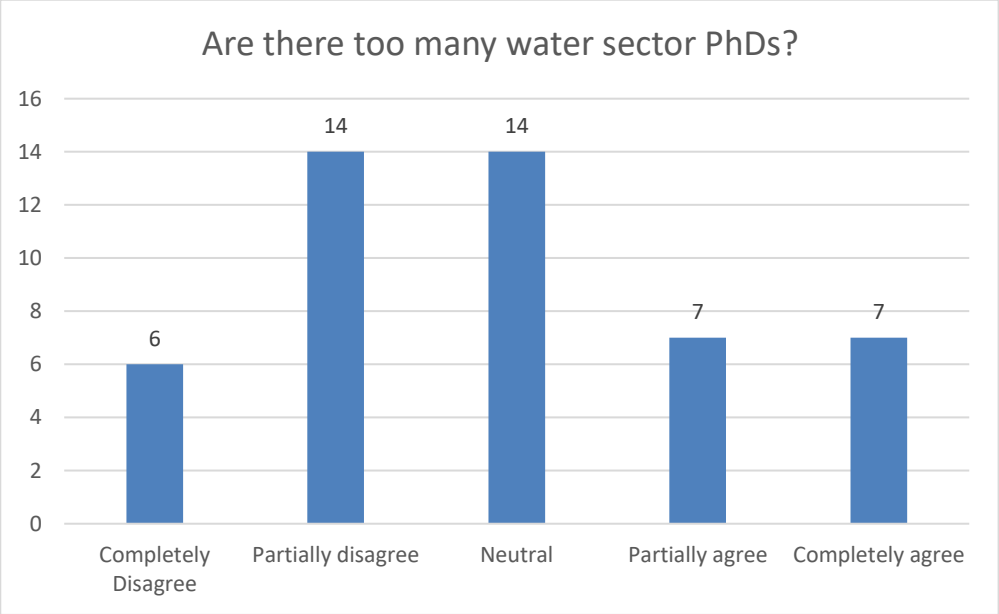

Figure 10: *Breakdown of opinions related to need for water sector PhDs*

A number of thematic pointers were picked up from the subjective responses received from the respondents. These themes are indicated within Box 2.

Theme 1: **It was seen that respondents with more than 5 years' experience were more inclined to state that there is need for more PhDs in the water sector across all domains (academia, government, private, etc.).** The need was identified based on the type of skills PhDs tend to have, ie, problem solving, research and investigation. A need for multi-disciplinary talent within the water sector

was also indicated, ie, PhDs that have skills in economics, engineering, social sciences and natural sciences are required to solve the challenges within the water sector. A number of respondents in managerial positions indicated that reduced funding has led to reduced research activities within organisations though there is a need for research.

Theme 2: **Respondents with less than 5 years of experience were inclined to indicate that the water sector currently has more PhDs than required.** This observation is likely to be closely related to the graduates' experience of looking for an initial employment opportunity post PhD completion. A number of post-doctoral fellows in academic institutions were uncertain about the possibility of the next position after completion of their current contract.

Theme 3: **Another identified theme within the subjective comments was a need to train PhDs in line with the needs of the broader industry** (private sector, water boards, semi-governmental research entities, etc.) particularly for technical research based roles. It was noted that these type of training initiatives would require better synergy between academia and broader industry.

Box 2: Subjective thematic pointers regarding the need of PhDs within water sector

DISCUSSION AND RECOMMENDATIONS

The objective of this investigation was to identify the employment trajectory of PhD-holders with theses related to water and sanitation awarded during the 2013-2017 period from South African Universities. More specifically the objectives of this investigation are as follows:

- Do we train too many or too few water-related PhDs?
- How mobile are doctorate-holders between sectors?
- When do doctorate-holders leave research for a career in management?
- Are water-related PhDs remaining in the country?
- Can we trace the work experience of water-related PhDs?

Furthermore, the findings of the investigation can express an opinion related to the appropriateness of current targets in the RDI Water Roadmap (2015).

These types of investigations – tracer surveys – also known as graduate destination surveys or alumni surveys are undertaken internationally informing policy authorities of the sectors benefiting from the PhDs; the PhD needs of the various sectors; the quality of the universities offering PhD studies, etc. In South Africa such investigations are rare and hence, the relevant information is also missing. The current document reports for first time in South Africa the employment status of PhDs in the water field. We suggest that this investigation is unique internationally focusing on water PhDs.

In this investigation we identified 112 PhD theses related to water. From the 112 identified relevant theses, contact details (in the form of either email addresses or phone numbers) were obtained for 100 doctorate graduates. Information for the individuals identified was collected from the social media and three rounds of emails with the questionnaire were sent out to the 100 identified respondents with the first round being

sent in November 2018, and follow up emails sent out in February 2019 and April 2019. It should be emphasised that the approach of identifying PhDs in the field of water through their theses is novel. Similarly the identification of relevant information for a tracer investigation from publicly available sources is not mentioned often in previous studies.

The findings identify that all PhD graduates were employed. Furthermore more than 50% of the PhD holders had positions in the university sector. Twenty three percent of those in academia had short term positions, e.g. post-doc positions. This finding leads to the conclusion that the country can absorb more PhD graduates in the field. This result coincides with the results in other countries where very small unemployment is identified for PhD graduates.

It is obvious that universities will attempt to keep all graduating PhDs that they need. Another interesting policy finding is the fact that approximately 30% of the PhD holders were in other African countries having gone back to their country of origin. This is an important policy issue of concern to Department of Higher Education and Training (DHET), Department of Science and Innovation (DSI) and Department of International Relations and Cooperation (DIRCO). The question is: Should South Africa provide educational facilities for the other African countries without appropriate cost recovery? A related issue to large number of PhDs from other countries raises the issue of benefits to the country from fees; living expenses; expenses from family and friends visiting the PhD candidates, etc. This issue requires further investigation not only for water PhDs but for all PhDs in all scientific disciplines. Similarly it is important to clarify the limitation in the production of PhDs for the needs of the economy

The investigation identified that approximately 90% of the respondents to questionnaire were in occupations related to the water sector. While this finding together with the finding that all PhD graduates were employed does not confirm the claim of the Water Roadmap that the system requires 200 PhDs per year (in order to achieve the Roadmaps objectives) it makes evident that under current market conditions PhDs can secure employment in the sector relevant to their field of training. It should be mentioned that the number of local water PhDs is less than the original estimates as a number of the PhDs leave for their countries.

An interesting question is why the local universities do not employ the foreign PhD graduates who return back to their country of origin. The legal and regulatory challenges (e.g. visas) are well known. However, Universities could increase their efforts to retain their PhDs in their employment and in the country.

It becomes apparent that water PhDs are in demand in South Africa and the majority find employment in the university sector. It will be important to identify whether the phenomenon is valid across other scientific disciplines as well or if it occurs only on the water-related PhDs.

Mobility between sectors was identified to be limited with 16% (i.e. 18 out of 112) of the graduates identified to have transitioned between sectors. However this finding should be seen in the context of 5-years span of PhD graduates and the large absorptive capacity of the university sector. Similarly 18% of the graduates declared that they had management experience, Again this was expected as the PhD graduates have been only for a limited time in the market place.

Seventy percent of the graduates remain in the country and 87.5% remain within the Africa Continent. PhD graduates in the water field remain in South Africa or they return to their country of origin. Again it is important to identify whether this pattern is valid for all scientific disciplines or it is a water specific characteristic.

Finally the work experience of the PhD holders was identified to be between 2 and 5 years (40.1%).

The investigation provides valuable information with policy implications. Probably the most important question to be raised is whether the identified results are unique in the water sector or they apply across the board in other sectors as well. It is suggested that a similar investigation covering the majority of broad scientific sectors in South Africa should be undertaken.

The large number of PhDs returning to their countries is also an issue requiring further investigation. Foreign students assist universities to export their services. Student living expenses, expenses from visiting family members and friends are among the tangible benefits to the country. The university expenses related to particular PhD candidate is the relevant costs. In South Africa there are no relevant estimates to guide policy.

The results should be included in the “State of South African Water Research” indicators. Following international good practise it is recommended that the exercise should be repeated every two years. Two years is short enough time so the participating PhDs will remember the exercise and respond again. Furthermore, the size of the population should be increasing according to the natural expansion and attempts should be made to include those who didn’t respond in the first survey.

REFERENCES

ASSAF (2010). *The PHD Study*. Consensus Report; Academy of Science of South Africa, Pretoria.

ASSAf (2018). *Status of Postgraduate Research Training in Engineering in South Africa.* Academy of Science of South Africa; Pretoria

Bhorat, H. (2004). "Labour Market Challenges in the post-Apartheid South Africa." *South African Journal of Economics*, 72(5):940-977

Blassoples, C. (2011). *The Determinants of Fit between the World of Work and Tertiary Learning: A Tracer Study of CPUT Marketing Diploma Graduates*. Cape Peninsula University of Technology

Botha, J. (2015). *A Desktop Study of Higher Education Tracer Studies in South Africa.* Centre for Research on Evaluation, Science and Technology, Stellenbosch.

CHEC (2013). *Pathways from University to Work.* Cape Higher Education Consortium; available at http://www.chec.ac.za/files/CHEC%20Graduate%20Survey%20FULL%20REPORT%20WEB.pdf

DPRU (2006). *Graduate Unemployment in Post-Apartheid South Africa: Nature and Possible Policy Responses.* Development Policy Research Unit; UCT.

ESF (2017). *2017 Career Tracking Survey of Doctorate Holders.* European Science Foundation available at http://www.esf.org/scientific-support/career-tracking-surveys-of-doctorate-holders/2017-career-tracking-survey-of-doctorate-holders/

Griesel, H. and Parker, B. (2008). *Graduate Attributes: A Baseline Study on South African Graduates from the Perspective of Employers.* Report to Higher Education South Africa (HESA) and the South African Qualifications Authority (SAQA), Pretoria.

Kraak, A. (2010). "The collapse of the graduate labour market in South Africa: evidence from recent studies." *Research in Post-Compulsory Education*, 15(1):81-102

Mouton, J. (1998). *Report on a Survey of South African DAAD Scholarship Holders.* Stellenbosch Centre for Research on Evaluation, Science and Technology, University of Stellenbosch

Mugabushaka, A., Teichler, U. and Schomburg, H. (2003). "Failed or Self-Hindering Prophecies? Employment Experiences of African Graduates in the 1990s." *Journal of Higher Education in Africa*, 1(1):57-77

NRF (2017). NEXUS: Current and Completed Research Projects. New Shared Workflow Proposal for HEI and the NRF. Accessed June 2018 http://ir.nrf.ac.za/bitstream/handle/10907/1480/nexus_workflow_proposal_2017.pdf?sequence=1&isAllowed=y

NSF (2018). *Survey of Earned Doctorates.* National Science Foundation available at https://nsf.gov/statistics/2018/nsf18304/static/report/nsf18304-report.pdf

OECD/Eurostat (1995). *Measurement of Scientific and Technological Activities: Manual on the Measurement of Human Resources Devoted to S&T – Canberra Manual.* OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264065581-en

OECD/UNESCO (2007). *Labour Market Characteristics and International Mobility of Doctorate Holders: Results for Seven Countries.* STI Working Paper 2007/2, Paris.

OECD (2010). *Mapping Careers and Mobility of Doctorate-holders.* OECD Science, Technology and Industry Working Papers 2010/1, Paris.

Pouris, A. (2018). *Mapping Out the Water Research, Development and Innovation Ecosystem in Relation to the Water Investment Priorities.* WRC Report.

QILT (2018). *Quality Indicators for Learning and Teaching.* Available at https://www.qilt.edu.au/about-this-site/student-experience

Shongwe, M. and Ocholla, D.N. (2011). "A Tracer Study of LIS Graduates at the University of Zululand 2000-2009." *Mousaion*, 29(2):227-245

Singh, R. (2010). *Career Trajectories of Masters in Education (MEd) Students: A Tracer Study of the MEd Class of 1999 at the University of the Witwatersrand*. University of the Witwatersrand

Van Broekhuizen, H. (2013). *Higher Education Institutions and Graduate Labour Market Outcomes in South Africa.* Bureau for Economic Research; Stellenbosch

Van den Berg, S. and Van Broekhuizen, H. (2012). *Graduate Unemployment in South Africa: A Much Exaggerated Problem.* Centre for Development and Enterprise, Stellenbosch

WRC/DST (2015). *South Africa's Water Research, Development, and Innovation (RDI) Roadmap: 2015-2025.* WRC Report No. 2305/1/15.

Yue, C. (2014). "A Comparative Study of Graduate Employment Surveys: 2003-2011." *Chinese Education & Society* 47(6): 12-35.

APPENDIX 1: Key-words Utilised for the Identification of PhD-holders

Adsorption	Irrigat*
Aqua*	Lake*
Aque*	Limnolog*
Aquifer	Marine
Arid	Micropollut*
Artificial + recharge	Pipe*
Basin*	Precipitat*
Bioaccumulation	Rain*
Biosorption	Riparian
Borehole	River*
Canal	Runoff*
Catchm*	Salin*
Dam	Sanitation
Desalination	Sediment*
Drain	Seepag*
Dredg*	Sludge
Drought	Snow
Eutrophication	Stream*
Effluent	Tidal
Estuar*	Toilet
Evaporat*	Waste*
Flood*	Water*
Frost	*Water
Hydrau*	Water
Hydro*	Wetland
Ice	Well

APPENDIX 2: Questionnaire

Water Sector PhDs Tracer Questionnaire

Introduction: The tracer study undertaken by the Water Research Commission, South Africa, aims to trace the employment profile of water sector doctoral graduates over the past five years in order to determine if doctoral graduates continue applying their skills within the same sector. As an important role-player within the sector your inputs to this exercise will be invaluable. (Please see page 3 for letter of support).

A) Particulars

1) First Name: *2) Surname:* *3) Gender:* *4) Title:* *5) Nationality:*

B) Current job details

1) Current Position/Designation:

2) Current Employer:

3) Current sector (Please select one from below):

a) Academia *b) Private* *c) Semi-governmental research entity* *d) Governmental* *e) NPO*

4) Current Location (Country):

5) Years of experience in current job position:

6) Years of managerial experience in current position:

C) Previous job details (only include job before current job and after PhD graduation if more than one)

1) Previous Position/Designation:

2) Previous Employer:

3) Previous sector (Please select one from below):

a) Academia b) Private c) Semi-governmental research entity d) Governmental e) g6NPO

4) Previous Location (Country):

5) Years of experience in previous job position:

6) Years of managerial experience in previous position:

7) Are you currently working in a field related to your PhD research or using aspects (such as methodology or frameworks) of your PhD? If yes, please provide details (in not more than two sentences) for continuing in the water sector.

_____
_____
_____
_____

8) If working in a sector different from your PhD research, please provide details (in not more than two sentences) reasons to move to a different sector.

_____
_____
_____
_____

9) Did the findings/results of your PhD thesis lead to any outputs in the form of journal papers, conference papers, patents, books, etc.? (if so, please provide details)

_____
_____
_____
_____

D) Opinions about current state of PhD human resources in the water sector

1) Do you think there is an abundance of PhD graduates in the water sector? (Please select one)

a) Completely disagree b) Partially disagree c) Neutral d) Partially agree e) Completely agree

2) If you completely or partially agree, please provide possible ways in which the water sector can absorb these PhD graduates?

_____
_____
_____
_____

3) If you think there is a lack of sufficient PhDs (i.e completely or partially disagree) PhD graduates in the water sector, please provide an indication of the roles within which these skills are required in your organisation or the sector as a whole?

_____
_____
_____
_____