

Fluorine Research in South Africa and Four Benchmarking Countries: Comparative Mapping and Assessment

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Abstract

Fluorine research has been identified as a priority area in South Africa and the South African Nuclear Energy Corporation (NECSA) is embarking in an effort to expand its hydrogen fluoride and aluminium trifluoride production capacity. On the eve of those efforts this article reports the findings of an effort to map and assess fluorine research in South Africa in comparison to four other countries i.e. Malaysia, Australia, Germany and Italy.

The results of the assessment are aimed at guiding future directions for fluorine research in the country, at identifying centres of expertise nationally where new research chairs could be established, at identifying international centres of expertise to be utilised for collaboration and of course for inter-temporal benchmarking of fluorine research in South Africa.

South Africa is identified to be producing a small number of fluorine research publications in comparison to other countries like Germany and Italy which produce orders of magnitude larger number of publications and in comparison to country's total research effort. Furthermore the relevant research effort appears to be dispersed geographically and in disciplinary terms. Relevant recommendations are provided with particular emphasis on the pluralistic science policy approach followed in the country.

Introduction

The element fluorine has been discovered by Henri Moissan in 1886 but the field was slow to grow initially. Recent scientometric studies (SCHUBERT, 1997; SCHOFIELD, 1999) show that fluorine research has become a fast growing field and thousands of articles in the field are produced annually covering a variety of multidisciplinary and inter-disciplinary issues. To the extent that the publishing of a subject specific journal marks the institutionalization of a new scientific field fluorine research saw its institutionalization process during 1971 when the Journal of Fluorine Chemistry was launched by Elsevier, Amsterdam.

The element fluorine played a distinctive technological role historically. Examples include the development of freons for the purpose of refrigeration in the 1930s, fluorine's role in the Manhattan project and after that its contribution to a number of fields including the fields of fluoropolymers, pharmaceuticals, agrochemicals, materials science and others. The Moissan prize was created after the Centennial 1986 Paris Symposium to commemorate Moissan's isolation of elemental fluorine in 1886, and to stimulate research in the fields of fluorine chemistry. It has been said that "the beginning of the 21st century, can authentically be considered a "renaissance" period for the field of fluorine chemistry" (DOLBIER, 2005)

In South Africa fluorine research has been identified as a priority area in the country's National R&D Strategy (DST, 2002). Moreover the South African Nuclear Energy Corporation (NECSA) is embarking in an effort to build a 30,000 t/y hydrogen fluoride (HF) and aluminium trifluoride (ATF) plant. It is estimated that around 60% of plant's production would be used in South Africa's aluminium, stainless steel, and petrochemicals and future refrigeration industries. Around 40% could be exported as high-value speciality and performance fluoro-chemicals.

The objective of this investigation is to assess the performance of South Africa in the field of fluorine research. The results of the investigation could guide future directions for fluorine research, they could identify centres of expertise nationally where new research chairs could be incorporated, they could identify international centres of expertise to be utilised for collaboration and of course the results of the investigation could be used for inter-temporal benchmarking of fluorine research in South Africa.

More specifically the investigation aims to identify the performance of South African research in the field of "fluorine" over a period of ten years, in comparison to other scientific fields in the country (e.g. chemical engineering; inorganic & nuclear chemistry etc) and in comparison to similar research in four comparator countries (i.e. Malaysia, Australia, Germany, Italy). In this context the centres of expertise in South Africa are identified in an objective way as well as the country's international collaborators.

Methodology and Sources of Information

Fluorine research is a multidisciplinary and inter-disciplinary endeavour. The variety of scientific fields affecting and contributing to fluorine research dictate that the information platform to be used for the identification of the relevant South African research articles should be multidisciplinary and geographically diverse in order to allow comparisons of the South African performance in different scientific disciplines and with the performance of a number of comparator countries. An additional requirement is that the databases should include the addresses of all co-authors (and not only of the first author) in order to permit identification of collaborative patterns and in order to identify all articles with a South African co-author and not only those with a South African first author.

In comparison to other fields of science and technology there is no readily available subject database or system for fluorine research. For example, there is only one journal dedicated to fluorine-science and it is almost impossible to identify a priori a fluorine-scientific community. Furthermore assessment through "peer-review" is particular difficult because South Africa is a scientifically small country (POURIS, 1988) and vested interests have the potentials to bias any analysis. Furthermore it is doubtful that any one individual could express an informed opinion about fluorine research across a number of disciplines and a number of countries. Consequently, the only way to assess fluorine research is through keywords scientometrically.

The ISI databases (Science Citation Index Expanded, Social Sciences Citation Index and Arts and Humanities Citation Index) were identified as the most appropriate for the objectives of the investigation. The combined databases cover comprehensively the most prestigious journals in the world in all fields of research endeavours and constitute a unique information platform for the objectives of this effort. The databases are used extensively for similar type of investigations (SALVADOR et al 2006; COSTAS et al (2005); LUWEL et al (1999); MOLATUDI et al 2006; POURIS, 2003; POURIS, 2007; CARAYANNIS et al 2004 and others)

While the ISI databases are among the most comprehensive sources of readily accessible information on national research outputs, they have certain limitations that have been discussed extensively in the literature (OKUBO 1997; COZZENS 1989;

CARPENTER 1981; GARFIELD 1979). However, in South Africa there is an effort by the educational authorities and the Universities administrations to publish mainly in the ISI journals. Hence, although a degree of incompleteness in coverage may exist, the majority of research in the field will be captured in the ISI databases.

The identified platform has been interrogated firstly for the identification of South African authors publishing in the field of fluorine-research during the last ten years and secondly for fluorine research in countries used for benchmarking purpose and research centres.

The relevant articles were extracted using text supplied 'fluorine-keywords" and combinations of relevant terms. The relevant "fluorine-words" were those constructed by the stem -fluoro; fluorin; and fluoride. Similarly the following combined terms were used as stems: hypofluor; polyfluor; perfluor; organofluor; oxyfluor; electrofluor; alkylperfluor; benzotrifluor; trifluor; sulphurfluor; polytetrafluor. The choice of the complex stem-words is based on the frequency of their appearance in a number of review articles (GAMBARETTO, 2004; HAGENMULLER, 2001; TATLOW, 1999; SCHOFIELD, 1999)

The developed database was analyzed in order to identify South African researchers who publish research related to fluorine; the institutions in which those researchers are engaged; their co-authorship patterns with other countries and institutions; the scientific field representation of the country's research; and trends over time.

The results of the analysis were compared with the performance of four other countries i.e. Malaysia, Australia, Germany, Italy. The four countries were chosen among those used for benchmarking exercises by the South African Department of Science and Technology and those which collaborate with South African institutions.

Fluorine Research in South Africa

Table 1 shows the number of number of fluorine publications with at least one author with South African address. The period covered is from July 1996 to June 2006 and hence the years 1996 and 2006 are partially covered. It becomes apparent that South Africa produces on average 81 relevant publications per year.

(TABLE 1 HERE)

Table 2 shows the number of South African publication in a number of scientific specialities and in fluorine research during the period 2000-2004. It should be mentioned that fluorine research is identified on the basis of key-words while the other disciplines are journal based. During the period South African researchers produced 19,397 publications hence in comparison the number of publications in the selected disciplines are relative small.

(TABLE 2 HERE)

Table 3 shows the institutions which produce fluorine research. The table shows the top (most prolific) institutions in the country. It becomes apparent that the top institutions in the field are the Universities of Witwatersrand and Pretoria having produced 17% and 15% of the fluorine publications respectively. However, even in these top institutions the number of research publications per year (around 12 articles) is small.

(TABLE 3 HERE)

In order to identify the relevant linkages of South African Universities with institutions abroad we examined collaborative patterns in greater detail. We set as threshold at least three collaborative publications during the period and we received the following linkages:

- University of Stellenbosch with Deutsh Kunststoff Inst Darmstadt; NCI; Chinese Acad Sci.; Hebrew Univ. Jerusalem; Tel Aviv Univ; Univ Basel Hosp; Univ Saskatchewan; Vrije Univ Amsterdam.
- University of Cape Town with Tech Univ Bergakad Freiberg; Lainz Hosp; Univ. Bristol.
- University of Pretoria with Univ. Texas; Dana Farber Canc Inst; Case Western Reserve Univ; Univ Dusseldorf.

- University of Witwatersrand with Emory Univ; Univ Queensland; Univ Zimbabwe; Vanerbilt Univ; Univ Massachusets.

Table 4 shows the disciplinary character of the fluorine based research produced in South Africa. Biochemistry & molecular biology and plant sciences are the top scientific fields contributing 8.1% and 7.7% of the relevant publications respectively. The field of dentistry/ oral surgery & medicine contributes 5.3% of the fluorine research in South Africa. The debate around water fluoridation (water fluoridation was introduced during 2003 in the country) is the contributing force behind the interest for publications in the field. Opponents of water fluoridation have even argued that such an action is unconstitutional. The table shows that fluorine research in South Africa revolves around life sciences related disciplines.

(TABLE 4 HERE)

Table 5 shows the countries with which South Africa collaborates in researching fluorine issues. The USA and Germany are identified as the countries with which SA collaborate in the production of their research. The two countries appear in 14.3% and 8.9% of the articles respectively.

(TABLE 5 HERE)

Table 6 shows the authors who appear most often in the list of the fluorine publications. Ford T.A. (School of Chemistry, University of KwaZulu Natal) and Alberts V. (Department of Physics, Rand Africaans University) are on the top of the list. They follow: Klugman K.P. (Respiratory and Meningeal Pathogens Research Unit, MRC); Nyokong T. (Department of Chemistry, Rhodes University) and von Holy A. (School of Molecular and Cell Biology, University of Witwatersrand).

(TABLE 6 HERE)

Identification of the specialisation in fluorine research of the top South African universities indicates that the University of Witwatersrand specialises in fluorine research related to microbiology and infectious diseases, the University of Pretoria in dentistry and veterinary sciences and the University of Cape Town in biochemistry and molecular biology. However all universities produce a relative small number of

publications which are the result of a small number of researchers in the field. Furthermore it should be emphasised that the identified priorities are “revealed” ones in the sense that Universities do not decide explicitly to emphasize particular area of fluorine research but their academics make choices and the table reveals the aggregate results of those choices. The emphasis on life sciences becomes also evident at this level of detail.

Fluorine research in Germany, Malaysia, Australia and Italy

In this section I map fluorine research in four countries with which South Africa compares itself or/and collaborates with. The countries are Germany, Malaysia, Australia and Italy. For each country I identify the number of their research publications, their most prolific institutions in the field of fluorine research and the disciplinary character of their fluorine research.

Table 7 shows the number of publications related to fluorine research produced by institutions in Germany, Malaysia, Australia and Italy. Germany produces above 3000 related publications per year with Italy following with 1400 publications per year and Australia with approximately 700 publications per year. Malaysia is producing the smallest number of research publications related to fluorine among the four comparator countries.

(TABLE 7 HERE)

Table 8 shows the most prolific institutions involved in fluorine research and their relevant outputs in the four countries under examination during the period (1996-2006).

(TABLE 8 HERE)

Table 9 shows the disciplinary character of fluorine research in the four countries. In Germany biochemistry & molecular biology and chemistry - physical are on top of the list contributing 11.7% and 7.7% respectively of the total effort. In Malaysia emphasis is placed in crystallography (17.02%) and chemistry-inorganic & nuclear (10.28%). Australia emphasises biochemistry & molecular biology (10.48%) and Italy biochemistry & molecular biology (12.69) and almost to the same extent oncology (11.27%). The

absence of the field of dentistry/oral surgery & medicine from the list of the most prolific disciplines in the examined countries is worth noting.

(TABLE 9 HERE)

All four countries appear to collaborate to a large extent with the same countries abroad. Germany collaborates with USA (11.0%), France (3.9%), England (3.6%) and Russia (2.8%). Malaysia collaborates with P.R. China (15.9%), India (7.8%), USA (7.1%) and England (6.4%). Australia collaborates with USA (15.0%), England (6.3%), Germany (5.5%) and Japan (3.4%). Italy collaborates with USA (10.5%), France (6.2%), Germany (5.6%) and England 4.6%).

Findings and discussion

In this document I developed the fluorine research profile of South Africa and those of four other countries-Germany, Italy, Australia and Italy.

(TABLE 10 HERE)

Table 10 shows that South Africa is producing a small number of fluorine research publications in comparison to other countries like Germany and Italy which produce orders of magnitude larger number of publications. Furthermore the table shows that not only the absolute number of publications is relatively small but also the share of fluorine publications to the national total is smaller in South Africa than in the other countries. While in Germany fluorine research constitutes 5.6% of the national total and in Italy 4.2% in South Africa the relevant ratio is 2.2%. The activity indices indicate the extent to which that country's research effort in the field of fluorine corresponds to the five countries average. An activity index bigger than one indicates a higher than average effort dedicated to the field under investigation while an index less than one indicates a smaller than average effort (FRAME 1977).The latter finding means that in South Africa fluorine research is underrepresented in the country's research efforts. The figures over a ten year period also show that fluorine research in South Africa is in a relatively flat trend.

The disciplinary characterization of the South African fluorine research identifies that emphasis is placed on life sciences (biochemistry & molecular biology, plant sciences

etc) and that the publications are distributed evenly to a number of scientific fields. In contrast in Malaysia, a country with fewer fluorine publications than South Africa, emphasis is placed in non life sciences and it is focused in a limited number of fields (crystallography 17% and inorganic and nuclear chemistry 10%).

The above findings conform to those of a pluralistic R&D system in the country. Fluorine research in South Africa (like many other scientific specialities/disciplines) is the result of the interests of individual researchers and not part of an orchestrated effort to develop particular lines of expertise and research in the country.

The Universities of Witwatersrand and Pretoria are identified as the most prolific institutions in the country in the field of fluorine research. Even though the article indicates lines of specialisations within the different institutions the small number of publications makes such analyses sensitive to movements and interests of individual researchers.

The Department of Science and Technology has embarked recently in the establishment of a number of research chairs (South African Research Chairs Initiative) in the country's universities in order to strengthen the country's research capabilities. It has been suggested that more than 250 chairs will be established in the course of the next few years. Universities are invited to apply for research chairs within their strategic plans and for a number of chairs in pre-selected directed research areas. Currently the only directed research chairs are in the fields of health technology, nano-technology, indigenous knowledge systems and pebble bed modular reactor (PBMR) related technology.

The small size of South African fluorine research in the country and its disciplinary distribution are indicative of the fact that South African universities do not promote the field of fluorine research. Consequently universities on their own will not apply for fluorine research chairs. It is suggested that if the Department of Science and Technology wishes to implement its plans related to fluorine it will have to introduce fluorine research among the set of the directed research chairs. At least two or three research chairs will have to be introduced emphasising the industrial and other disciplines that will be required for NECSA's expansion plans.

Comparison of the collaborative patterns of South African fluorine research with those of the four countries indicates that all five countries collaborate with USA and England and that Germany is among the top four collaborating countries to Italy, Australia and South Africa. It should be noted that USA and Germany are among the most prolific fluorine research publishers in the World. USA produces 31% of the World's research (2004 to July 2006) and Germany 9.8% of the World's research. Japan is the second most prolific country in the field of fluorine research producing 11.3% of the World's research in the field.

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Table 1: Number of fluorine publications from SA 1996-2006

Publication Year	Number of publications
1996	14
1997	70
1998	80
1999	81
2000	85
2001	78
2002	82
2003	77
2004	99
2005	79
2006	45

Table 2: SA publications 2000-2004, selected disciplines

Scientific discipline	Number of publications
Applied Physics, condensed matter, material science	513
Fluorine research	331
Organic chemistry, polymer science	326
Chemical engineering	222
Inorganic and nuclear chemistry	187
Nuclear engineering	15

Table 3: SA institutions producing fluorine research 1996-2006

Institution Name	Record Count	% of 790
UNIV WITWATERSRAND	135	17.08%
UNIV PRETORIA	120	15.18%
UNIV CAPE TOWN	107	13.54%
UNIV STELLENBOSH	106	13.41%
UNIV NATAL	63	7.97%
RHODES UNIV	44	5.56%
UNIV ORANGE FREE STATE	32	4.05%
RAND AFRIKAANS UNIV	28	3.54%
POTCHESFSTROOM UNIV	25	3.16%
MRC	19	2.40%
GROOTE SCHUUR HOSP	18	2.27%
UNIV KWAZULU NATAL	16	2.02%
S AFRICAN INST MED RES	11	1.39%
UNIV WESTERN CAPE	10	1.26%
VISTA UNIV	10	1.26%
CSIR	9	1.13%
JOHANNESBURG HOSP	9	1.13%
ONDERSTEPOORT VET INST	9	1.13%
UNIV PORT ELIZABETH	9	1.13%
NATL INST VIROL	8	1.01%
TYGERBERG HOP	8	1.01%
UNIV DURBAN WESTVILLE	8	1.01%

Table 4: Disciplinary character of SA fluorine research 1996-2006

Subject Category	Record Count	% of 790
BIOCHEMISTRY & MOLECULAR BIOLOGY	64	8.10%
PLANT SCIENCES	61	7.72%
MICROBIOLOGY	49	6.20%
CHEMISTRY, MULTIDISCIPLINARY	48	6.07%
DENTISTRY, ORAL SURGERY & MEDICINE	42	5.31%
CHEMISTRY, PHYSICAL	38	4.81%
PHARMACOLOGY & PHARMACY	37	4.68%
CHEMISTRY, ANALYTICAL	31	3.92%
BIOTECHNOLOGY & APPLIED MICROBIOLOGY	29	3.67%
INFECTIOUS DISEASES	28	3.54%
ONCOLOGY	28	3.54%
VETERINARY SCIENCES	28	3.54%
IMMUNOLOGY	26	3.29%
WATER RESOURCES	26	3.29%
ENVIRONMENTAL SCIENCES	24	3.03%
MATERIALS SCIENCE, MULTIDISCIPLINARY	22	2.78%
MULTIDISCIPLINARY SCIENCES	22	2.78%
CELL BIOLOGY	20	2.53%
ENGINEERING, CHEMICAL	20	2.53%
GENETICS & HEREDITY	18	2.27%
MARINE & FRESH WATER BIOLOGY	18	2.27%
PHYSICS, CONDENSED MATTER	18	2.27%
BIOCHEMICAL RESEARCH	17	2.15%

Table 5: Collaborative patterns of SA fluorine research 1996-2006

Field: Country/ Territory	Record Count	% of 790
USA	113	14.30%
GERMANY	71	8.98%
ENGLAND	55	6.96%
AUSTRALIA	34	4.30%
ITALY	23	2.91%
FRANCE	21	2.65%
CANADA	20	2.53%
SWITZERLAND	20	2.53%
BELGIUM	17	2.15%
AUSTRIA	16	2.02%
NETHERLANDS	15	1.89%
JAPAN	12	1.51%
SWEDEN	12	1.51%
SCOTLAND	11	1.39%
ISRAEL	10	1.26%
POLAND	9	1.13%
SPAIN	9	1.13%
ZIMBABWE	8	1.01%
NORWAY	7	0.88%
PEOPLES R CHINA	7	0.88%
DENMARK	6	0.75%
INDIA	6	0.75%
RUSSIA	6	0.75%
SLOVENIA	6	0.75%

Table 6: Authors producing SA fluorine research 1996-2006

Field Author	Record Count	% of 790
FORD, TA	19	2.40%
ALBERTS, V	17	2.15%
KLUGMAN, KP	14	1.77%
NYOKONG, T	14	1.77%
VON HOLY, A	13	1.64%
CAIRA, MR	12	1.51%
DIRR, HW	11	1.39%
KRUGER, GHJ	11	1.39%
NXUMALO, LM	11	1.39%
ROBINSON, TJ	11	1.39%
LINDSAY, D	10	1.26%

Table 7: Number of publications-Selected countries 1996-2006

Publication Year	Germany	Malaysia	Australia	Italy
1997	2665	16	507	1103
1998	2874	20	538	1106
1999	2965	28	544	1123
2000	3155	28	585	1137
2001	3183	25	581	1218
2002	3242	27	592	1232
2003	3291	39	679	1277
2004	3398	44	672	1459

2005	3722	41	734	1451
2006	1760	14	399	787

Table 8: Most prolific institutions producing fluorine research: selected countries

Germany: Institution Name	Record Count	% of 30518
UNIV MUNICH	1487	4.87%
UNIV HEIDELBERG	1193	3.90%
TECH UNIV MUNICH	1037	3.39%
HUMBOLDT UNIV	950	3.11%
UNIV TUBINGEN	907	2.97%

Malaysia: Institution Name	Record Count	% of 282
UNIV MALAYA	97	34.39%
UNIV SAINS MALAYSIA	68	24.11%
UNIV KEBANGSAAN MALAYSIA	24	8.51%
NANJING UNIV	22	7.80%
UNIV TEKNOLOGI MALAYSIA	22	7.80%

Australia: Institution Name	Record Count	% of 5873
UNIV SYDNEY	641	10.91%
UNIV QUEENSLAND	581	9.89%

UNIV MELBOURNE	535	9.10%
MONASH UNIV	463	7.88%
AUSTRALIAN NATL UNIV	448	7.62%

Italy: Institution Name	Record Count	% of 12013
CNR	1600	13.31%
UNIV MILAN	847	7.05%
UNIV BOLOGNA	694	5.77%
UNIV PADUA	689	5.73%
UNIV PISA	505	4.20%

Table 9: Disciplinary character of fluorine research - selected countries

Germany: Subject Category	Record Count	% of 30518
BIOCHEMISTRY & MOLECULAR BIOLOGY	3595	11.77%
CHEMISTRY, PHYSICAL	2365	7.74%
CELL BIOLOGY	1752	5.74%
PHYSICS, ATOMIC, MOLECULAR & CHEMICAL	1612	5.28%
CHEMISTRY, INORGANIC & NUCLEAR	1560	5.11%
ONCOLOGY	1530	5.01%
CHEMISTRY, ORGANIC	1519	4.97%
CHEMISTRY, MULTIDISCIPLINARY	1490	4.88%
CHEMISTRY, ANALYTICAL	1264	4.14%
BIOPHYSICS	1184	3.87%

BIOCHEMICAL RESEARCH METHODS	1130	3.70%
PHARMACOLOGY & PHARMACY	1114	3.65%
RADIOLOGY, NUCLEAR MEDICINE & MEDICAL IMAGING	1076	3.52%
MICROBIOLOGY	1009	3.30%
GENETICS & HEREDITY	1003	3.28%

Malaysia: Subject Category	Record Count	% of 282
CRYSTALLOGRAPHY	48	17.02%
CHEMISTRY, INORGANIC & NUCLEAR	29	10.28%
CHEMISTRY, ANALYTICAL	19	6.73%
POLYMER SCIENCE	16	5.67%
BIOCHEMISTRY & MOLECULAR BIOLOGY	15	5.31%
MATERIALS SCIENCE, MULTIDISCIPLINARY	15	5.31%
ENVIRONMENTAL SCIENCES	13	4.60%
OPTICS	13	4.60%
CHEMISTRY, PHYSICAL	12	4.25%
FOOD SCIENCE & TECHNOLOGY	12	4.25%
BIOCHEMICAL RESEARCH METHODS	11	3.90%
ELECTROCHEMISTRY	11	3.90%
CHEMISTRY, APPLIED	10	3.54%
CHEMISTRY, MULTIDISCIPLINARY	10	3.54%
PHARMACOLOGY & PHARMACY	10	3.54%

Australia: Subject Category	Record Count	% of 5873
BIOCHEMISTRY & MOLECULAR BIOLOGY	616	10.48%
PLANT SCIENCES	390	6.64%

CHEMISTRY, PHYSICAL	314	5.34%
CELL BIOLOGY	290	4.93%
BIOTECHNOLOGY & APPLIED MICROBIOLOGY	250	4.25%
MICROBIOLOGY	242	4.12%
ONCOLOGY	240	4.08%
GENETICS & HEREDITY	223	3.79%
BIOCHEMICAL RESEARCH METHODS	222	3.78%
NEUROSCINECES	214	3.64%
PHYSICS, ATMOIC, MOLECULAR & CHEMICAL	205	3.49%
CHEMISTRY, ANALYTICAL	202	3.43%
CHEMISTRY, MULTIDISCIPLINARY	186	3.16%
MARINE & FRESHWATER BIOLOGY	184	3.13%
OPTICS	168	2.86%

Italy: Subject Category	Record Count	% of 12033
BIOCHEMISTRY & MOLECULAR BIOLOGY	1527	12.69%
ONCOLOGY	1357	11.27%
CHEMISTRY, PHYSICAL	783	6.50%
CHEMISTRY, ORGANIC	688	5.71%
PHARMACOLOGY & PHARMACY	325	5.19%
CELL BIOLOGY	598	4.96%
BIOPHYSICS	564	4.68%
CHEMISTRY, ANALYTICAL	551	4.57%
GENETICS & HEREDITY	514	4.27%
CHEMISTRY, MULTIDISCIPLINARY	444	3.68%
PHYSICS, ATOMIC, MOLECULAR & CHEMICAL	427	3.54%

BIOCHEMICAL RESEARCH METHODS	366	3.04%
CHEMISTRY, INORGANIC & NUCLEAR	354	2.94%
HEMATOLOGY	338	2.80%
MATERIALS SCIENCE, MULTIDISCIPLINARY	334	2.77%

Table 10: Number of fluorine publications, South Africa and selected countries

Country	Record FI.Count 2004- 2005	% of national total	Activity Index
Germany	7120	5.6	1.20
Italy	2910	4.2	0.90
Australia	1406	3.0	0.65
South Africa	178	2.2	0.48
Malaysia	85	3.6	0.78