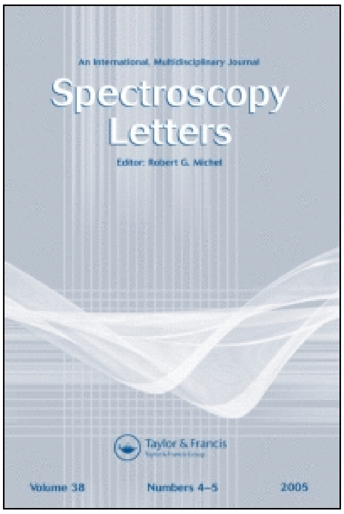

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Scientometric Picture of the Evolution of the Literature of Automation in Spectroscopy and Its Current State

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Scientometric Picture of the Evolution of the Literature of Automation in Spectroscopy and Its Current State

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Abstract: The current study focuses on the status of automation and mechanization in spectroscopy for analytical chemistry publications compiled during the period 1980–2006, in *Analytical Abstracts*. Flow injection analysis (FIA), sequential injection analysis (SIA), multicommutation, and monosegmented and segmented flow strategies were considered. For assessing the evolution of scientific productivity, the total number of publications concerned with the different methodologies was evaluated. In order to provide a picture of the state of the art of this field, the most important journals, the most active authors, and the most productive countries in the field of automation were evaluated in the period of the first years of this century.

Keywords: Automation, FIA, mechanization, multicommutation, scientometric, SIA, spectroscopy

INTRODUCTION

Statistics on publications, references, citations, and other bibliographical items have been called scientometrics or bibliometrics. Milestone papers on this topic were published 30 years ago,[1,2] but scientometrics continues to be an excellent tool for the evaluation of a research subject.

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Based on the definition of scientometry given by Weley-Tanaskovic et al.,[3] it is a scientific subject that analyzes and compares scientific and technological information, often in graphical form using mathematical methods including statistics and data analysis.[4] So, the main task of scientometry is to answer the question, "Who is doing what, and where?".

Two types of evaluation can be done using scientific and technological information: "metric evaluation" of the flow of information (articles and journals) and "quality evaluation" of information processed in databases. Graphical representation in the form of schemes reflects fields of research and the participants (researchers, institutions, countries). The objective is to provide a representation of the structure of information at any given time in its development.

There are various scientometric indices for accessing national and personal research performance and effort. The most commonly used ones are the evaluation of scientific disciplines,[5,6] national scientific production,[7] and bibliographic databases,[8,9] and they provide valuable tools to describe the scientific activity and to orient future research.

In the development of automation, the main milestones correspond with the first paper published by Skeggs in 1957 corresponding with the use of segmented flow,[10] that of Ruzicka and Hansen in 1975 corresponding with FIA,[11] the paper of Pasquini and Oliveira regarding monosegmented flow,[12] and those of Ruzicka and Marshall for SIA[13] and Reis et al. for multicommutation.[14]

Automation and mechanization have experienced a spectacular increase in the last decades.[15,16] Advances in both instrumentation and software control at the beginning of the 21st century have contributed to impel automated or mechanized procedures.

Also, spectroscopy and spectrometry techniques have been improved with the progress of automation[17–19] in terms of an increase in laboratory productivity, reduction of the consumption of reagents and toxic solvents, and ease of sample introduction and sample treatment.

In the current article, scientific productivity in analytical chemistry and the impact of automation in spectroscopy are assessed. The period from 1980 to 2006 has been used to evaluate the evolution of the literature in this field, and the most relevant research groups on this area were identified from their productivity in the first years of the 21st century.

The main keywords employed to recover the scientific literature were (spectroscopy or spectrometry or spectrophotometry or photometry) and (automation or automated or mechanization or mechanized or multicommutation or multicommutated or multicommuted or micropumping or fia or flow injection or sia or sequential injection or monosegmented flow or segmented flow).

THE EVOLUTION OF THE LITERATURE ON AUTOMATION AND SPECTROMETRY

A total number of 8279 papers compiled in the *Analytical Abstracts* from the period January 1980 to March 2006 were taken into account, and it must be noticed that half part of these were published from January 2000 till now.

Figure 1 depicts the evolution of the accumulated number of published papers on automated spectroscopy and spectrometry, also including the evolution of the literature of the five main automated techniques; such as flow injection analysis (FIA), sequential injection analysis (SIA), multicommutation, and monosegmented and segmented flow.

A clear growth can be identified in the rate of scientific literature production at the beginning of the 1990s in all the aforementioned areas. This increase was more noticeable in FIA, multicommutation, and segmented flow. The multicommutation technique has had an exponential growth in the past 6 years, with the total number of published papers being multiplied by a factor of 3, indicating the current importance of multicommutated studies.

On considering the automated applications of spectroscopy-based scientific papers, it can be seen (Fig. 1c) that 81.4% of the total published papers correspond with FIA, 15.9% with SIA, 1.3% with multicommutation, 1.1% with segmented flow, and 0.4% with monosegmented flow techniques, which is close to the real situation in the market of automated instrumentation, but also indicates the tremendous impact of academic studies clearly reflected by the reduced weight of segmented, monosegmented flow and multicommutation studies as compared with FIA and SIA-based ones, at the present time.

THE SOURCES OF LITERATURE IN THE 21ST CENTURY

The 4362 research papers published from the year 2000 in the field of automation and spectroscopy appeared in 157 scientific journals.

Figure 2 clearly shows that only three journals published 31.8% of the literature in the field: *Analytica Chimica Acta*, *Talanta*, and *Analytical Chemistry*. These journals are general publications in analytical chemistry, which evidences the importance of automation in general analysis techniques. *Analytica Chimica Acta* is the main publishing medium in this field with an outstanding percentage of 12.9%. On the other hand, 49 of the aforementioned journals only published 1 single paper in this field during the first years of the century, 22 published 2 papers, 15 journals 3 contributions, and 7 published 4 papers.

Journals on atomic spectroscopy and chromatography were among the main sources of automation studies, thus indicating the special importance of automation in these fields.

ACTIVE RESEARCH GROUPS IN THE 21ST CENTURY

Papers published on automation and spectroscopy have been written by different entities. The past 6 years has seen 52.7% of the accumulated scientific literature since 1980.

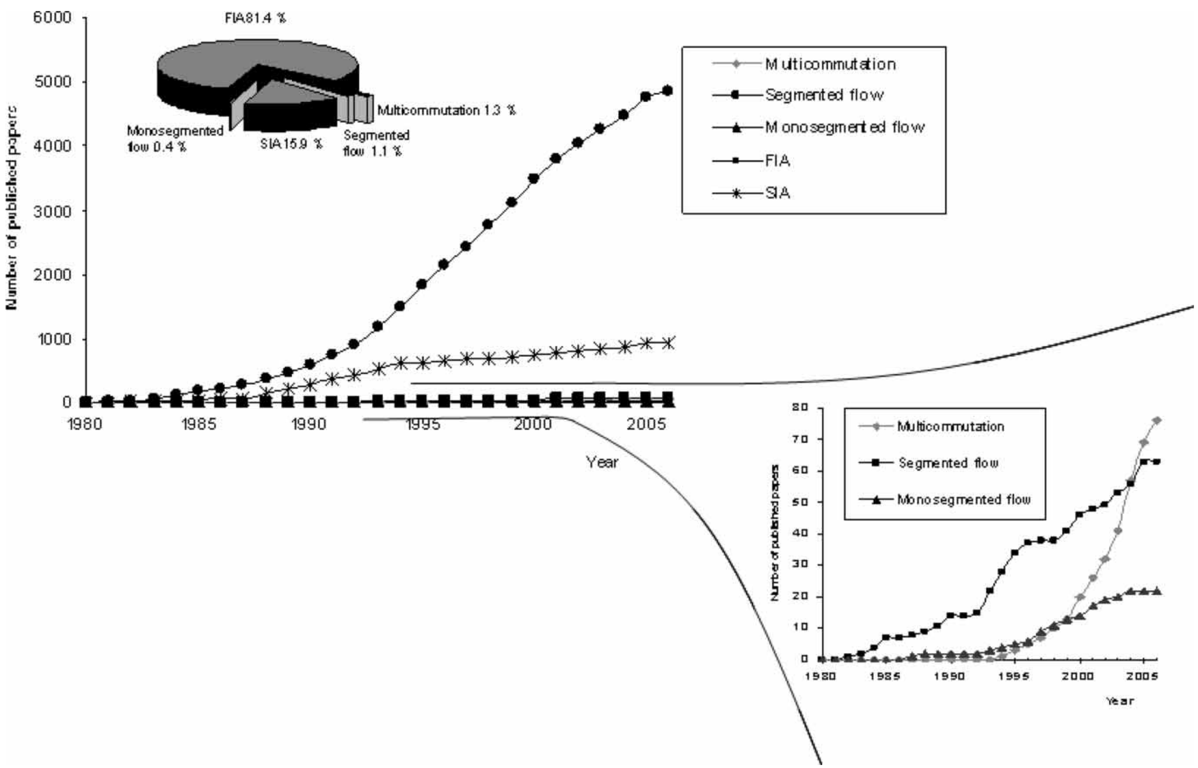

Figure 1. Evolution of the literature published on automation and spectroscopy. Note: 8279 total published papers. Figure 1c indicates the distribution of the literature on automated spectroscopy as a function of the approach employed. (Source: *Anal. Abstr.* 1980–2006.)

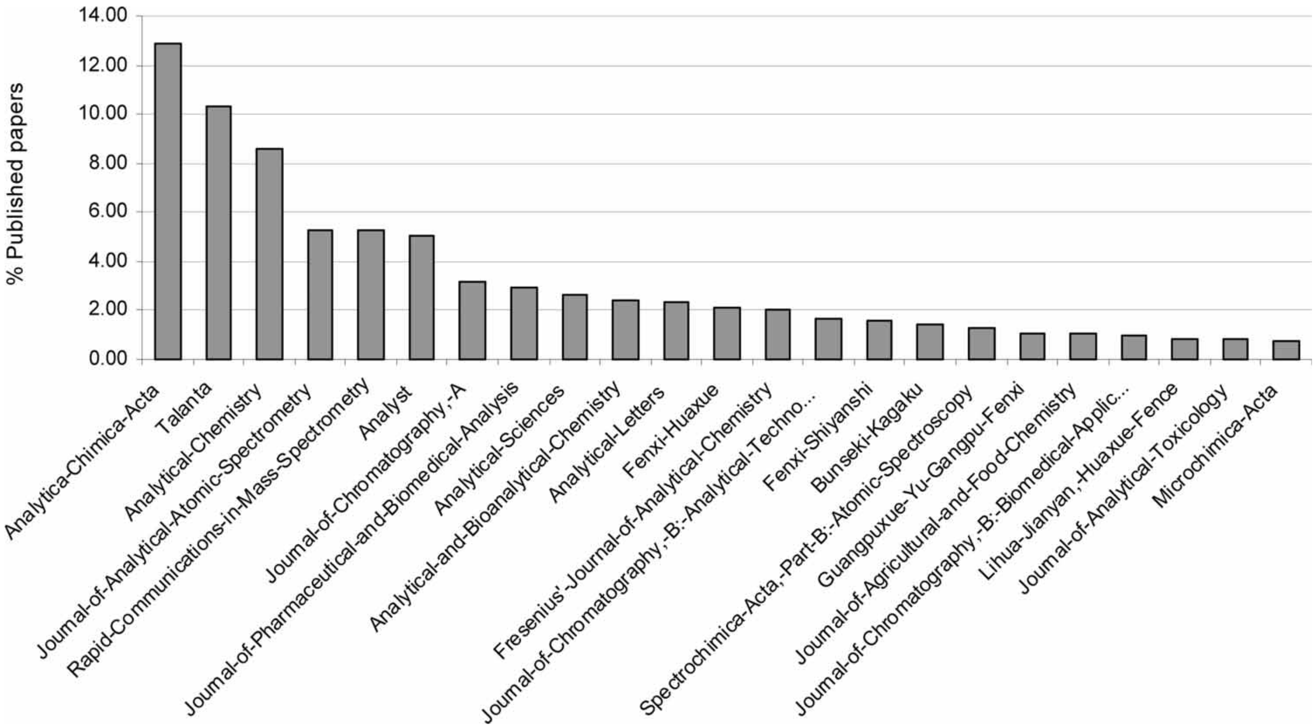

Figure 2. Distribution of the research papers published on automation and spectroscopy in the 21st century (2000–2006) as a function of the journal in which they appeared. (Source: *Anal. Abstr.*)

The 4362 papers were written by 5631 different authors with an average of nearly three authors per paper. The exact number is not quite certain because of several variants of some names and the possible homonyms. A quite large percentage (70%) of the authors contributed only once. On the other hand, a small group of the most productive scientists (2.6% of the authors; see Table 1) were among the authors of 64% of the published papers in this century.

Table 1 shows the most productive authors from the *Analytical Abstracts* database between the years 2000 and 2006, as a function of the number of published papers. A first group can be identified as six research teams who have published between 37 and 25 papers, the Olsina and Martínez team from Argentina, Reis in Brazil, Hansen and Wang from Denmark and China, and three different groups in Spain: those located in Valencia, Córdoba, and Mallorca. A second set of research groups with a number of published papers between 24 and 10 was located in different countries around the world like Spain, Thailand, Portugal, China, Greece, Argentina, Austria, Canada, Venezuela, South Africa, Japan, The Netherlands, United States, Sweden, Brazil, Belgium, and Iran. So, it can be concluded that there are many active research teams in this field who guarantee the future of this scientific practice.

GEOGRAPHIC ORIGIN OF THE LITERATURE PUBLISHED ON AUTOMATION AND SPECTROSCOPY

Countries of origin can be assigned to papers according to the corporate addresses indicated in the byline of the papers or given as a footnote in the *Analytical Abstract* database. All addresses of all contributing authors, from 2000 to 2006, were considered and each contributing country was counted exactly once.

A total of 22 countries contributed in the publication of automation and spectroscopy during the 21st century. All of them are shown in Fig. 3, where the number of papers is given as a percentage. As can be seen in the figure, Spain and the United States are the most productive countries and their contributions represent 27.2% of the total published papers. A second group of countries (Germany, China, Brazil, United Kingdom, Japan, and Canada) is in charge of 46.3% of the production. The rest of the countries contribute in a reduced percentage.

ANALYTICAL TECHNIQUES INVOLVED IN AUTOMATION STUDIES

In recent years, flow automated approaches like FIA, SIA, and multicommutation have been incorporated in the spectroscopy and spectrometry fields in

Table 1. Identification of the most productive research groups on automated spectroscopy at the beginning of the 21st century

Author	Number of papers	Co-workers	Institution
Martínez,-LD	37		Dept. Anal. Chem., Fac. Chem., Biochem. and Pharm., Natl. Univ. San Luis, 5700 San Luis, Argentina
de-la-Guardia,-M	35		Dept. Anal. Chem., Fac. Chem., Univ. Valencia, 46100 Burjassot, Valencia, Spain
Olsina,-RA	33	With Martinez LD	Dept. Anal. Chem., Fac. Chem., Biochem. and Pharm., Natl. Univ. San Luis, 5700 San Luis, Argentina
Reis,-BF	31		Centro Energia Nuclear Agric., Univ. Sao Paulo, Piracicaba 13400-970, Brazil
Hansen,-EH	31	With Wang JH	Dept. Chem., Tech. Univ. Denmark, 2800 Kgs. Lyngby, Denmark
Cerda,-V	27		Dept. Chem., Fac. Sci., Univ. Balearic Islands, 07122 Palma de Mallorca, Spain
Valcárcel,-M	25		Dept. Anal. Chem., Univ. Cordoba, 14071 Cordoba, Spain
Miro,-M	25	With Cerdá V	Dept. Chem., Univ. Balearic Islands, 07122 Palma de Mallorca, Spain
Wang,-JH	25	With Hansen EH	Res. Center Anal. Sci., Northeastern Univ., Shenyang 110006, China
Luque-de-Castro, MD	24		Anal. Chem. Div., Univ. Cordoba, 14071 Cordoba, Spain
Morales-Rubio,-A	23	With de la Guardia M	Dept. Quim. Anal., Univ. Valencia, 46100 Burjassot, Valencia, Spain
Grudpan,-K	23		Dept. Chem., Fac. Sci., Chiang Mai Univ., Chiang Mai 50200, Thailand
Lima,-JLFC	22		REQUIMTE/Dept. Quim.-Fis., Fac. Farm., Univ. Porto, Porto, Portugal
Yebra,-MC	22		Dept. Anal. Chem., Univ. Santiago Compostela, 15782 Santiago Compostela, Spain
Moreno-Cid,-A	21	With Yebra MC	Dept. Anal. Chem., Nutrition and Bromatol., Fac. Chem., Univ. Santiago de Compostela, 15782 Santiago de Compostela, Spain

(*continued*)

Table 1. Continued

Author	Number of papers	Co-workers	Institution
Garrigues,-S	20	With de la Guardia M	Dept. Anal. Chem., Univ. Valencia, 46100 Burjassot, Valencia, Spain
Yan,-XP	20		State Key Lab. Functional Polymer Materials Adsorption and Separation, and Res. Center Anal. Sci., Coll. Chem., Nankai Univ., Tianjin 300071, China
Themelis,-DG	20		Lab. Anal. Chem., Dept. Chem., Aristotle Univ. Thessaloniki, 54124 Thessaloniki, Greece
Wuilloud,-RG	20	With Martinez LD	Area Quim. Anal., Fac. Quim., Bioquim. Pharm., Univ.Natl. San Luis, Chacabuco y Pedernera, 5700 San Luis, Argentina
Lendl,-B	19		Inst. Chem. Technol. and Anal., Vienna Univ. Technol., 1060 Vienna, Austria
Pawliszyn,-J	19		Dept. Chem., Univ. Waterloo, Waterloo, ON N2L 3G1, Canada
Burguera,-JL	19	With Burguera M	IVAIQUIM, (Venezuelan Andean Inst. Chem. Res.), Fac. Sci., Los Andes Univ., Merida 5101-A, Venezuela
Burguera,-M	19	With Burguera JL	IVAIQUIM, (Venezuelan Andean Inst. Chem. Res.), Fac. Sci., Los Andes Univ., Merida 5101-A, Venezuela
Tzanavaras,-PD	18	With Themelis DG	Lab. Anal. Chem., Aristotle Univ. Thessalonika, 54006 Thessalonika, Greece
Jiang,-Y	18		State Key Lab. Functional Polymer Materials Adsorption and Separation, and Res. Center Anal. Sci., Coll. Chem., Nankai Univ., Tianjin 300071, China
Chen,-XG	17		Dept. Chem., Lanzhou Univ., Lanzhou 730000, China
van-Staden,-JF	17		Dept. Chem., Univ. Pretoria, Pretoria 0002, South Africa
Cano-Pavon,-JM	16		Dept. Anal. Chem., Fac. Sci., Univ. Malaga, 29071 Malaga, Spain

(*continued*)

Table 1. Continued

Author	Number of papers	Co-workers	Institution
Rangel,-AOSS	16		Escola Superior Biotecnol., Univ. Catolica Portuguesa, 4200-072 Porto, Portugal
Motomizu,-S	16		Dept. Chem., Fac. Sci., Okayama Univ., Okayama 700-0084, Japan
Jakmunee,-J	16	With Grudpan K	Dept. Chem., Fac. Sci., Chiang Mai Univ., Chiang Mai 50200, Thailand
Gasquez,-JA	16	With Martinez LD	Fac. Quim., Bioquim. y Farm., Univ. Nacl. San Luis Chacabuco y Pedernera, 5700 San Luis, Argentina
Barcelo,-D	16		Dept. Environ. Chem., IIQAB-CSIC, 08034 Barcelona, Spain
Cerutti,-S	16	With Martinez LD	Fac. Chem., Biochem. and Pharm., Natl. Univ. San Luis, 5700 San Luis, Argentina
Irth,-H	16		AR.de.Boer@few.vu.nl, Dept. Chem. and Pharm. Sci., Vrije Univ. Amsterdam, 1081 Amsterdam, Netherlands
Smith,-RD	16		Environ. and Mol. Sci. Lab., Pacific Northwest Natl. Lab., Richland, WA 99352, USA
Marko-Varga,-G	16		AstraZeneca RandD, 221 87 Lund, Sweden
Gallego,-M	15	With Valcárcel M	Dept. Anal. Chem., Univ. Cordoba, 14071 Cordoba, Spain
Hu,-ZD	15	With Chen XG	Dept. Chem., Lanzhou Univ., Lanzhou 730000, China
Estela,-JM	15	With Cerdá V	Dept. Chem., Fac. Sci., Univ. Balearic Islands, 07122 Palma de Mallorca, Spain
Fang,-ZL	15		Res. Centre Anal. Sci., Northeastern Univ., Shenyang 110004, China
Rocha,-FRP	14	With Fatibello O Filho and Reis BF	Inst. Quim., Univ. Sao Paulo, 05513-970 Sao Paulo, Brazil
Zagatto,-EAG	14	With Reis BF	Centro Energia Nuclear Agric., Univ. Sao Paulo, Piracicaba, SP 13400-970, Brazil

(*continued*)

Table 1. Continued

Author	Number of papers	Co-workers	Institution
Tang,-ZY	14		Fac. Material Sci. and Chem. Eng., China Univ. Geosci., Wuhan 430074, China
Liu,-P	14		Dept. Chem., Lanzhou Univ., Lanzhou 730000, China
Brinkman,-UAT	14		Dept. Anal. Chem. and Applied Spectroscopy, Vrije Univ., 1081 HV Amsterdam, Netherlands
Benkhedda,-K	13	With Adams FC	Micro-Trace Anal. Centre, Dept. Chem., Univ. Antwerp, 2610 Antwerp, Belgium
Fan,-J	13	With Feng SL	Key Lab. Environ. Sci. and Eng. Henan Education Dept., School Chem. and Environ. Sci., Henan Normal Univ., Xinxiang 453002, China
Feng,-SL	13		Key Lab. Environ. Sci. and Eng. Henan Education Dept., School Chem. and Environ. Sci., Henan Normal Univ., Xinxiang 453002, China
Martinez-Calatayud,-J	13		Dept. Anal. Chem., Univ. Valencia, Valencia 46100, Spain
Garcia-de-Torres,-A	13	With Cano Pavon JM	Univ. Malaga, Dept. Anal. Chem., Fac. Sci., 29071 Malaga, Spain
Pu,-QS	13	With Su ZX	Dept. Chem., Lanzhou Univ., Lanzhou 730000, China
Su,-ZX	13		Dept. Chem., Lanzhou Univ., Lanzhou 730000, China
Curtius,-AJ	13		Dept. Quim., Univ. Fed. Santa Catarina, 88040-900 Florianopolis, Brazil
Calafat,-AM	13		Div. Lab. Sci., Natl. Center Environ. Health, Centers Disease Control and Prevention, Atlanta, GA 30341, USA
Needham,-LL	13	With Calafat AM	Div. Lab. Sci., Natl. Center Environ. Health, Centers Disease Control and Prevention, Atlanta, GA 30341, USA
Tyson,-JF	13		Dept. Chem., Univ. Massachusetts, Amherst, MA 01003-9306, USA

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Table 1. Continued

Author	Number of papers	Co-workers	Institution
Rodenas-Torralba,-E	12	With de la Guardia M	Dept. Quim. Anal., Univ. Valencia, 46100 Burjassot, Valencia, Spain
Anthemidis,-AN	12		Lab. Anal. Chem., Dept. Chem., Aristotle Univ., Thessaloniki 54124, Greece
Stratis,-JA	12	With Anthemidis AN	Lab. Anal. Chem., Dept. Chem., Aristotle Univ., Thessaloniki 54124, Greece
Teshima,-N	12		Dept. Applied Chem., Fac. Eng., Aichi Inst. Tech., Toyota 470-0392, Japan
Oshima,-M	12	With Motomizu S	Dept. Chem., Okayama Univ., Okayama 700-8530, Japan
Ferreira,-SLC	12		Univ. Federal Bahia, 40170-290 Salvador, BA, Brazil
Small,-GW	12		Dept. Chem. and Biochem., Center Intelligent Chem. Instrumentation, Clippinger Lab., Ohio Univ., Athens, OH 45701-2979, USA
Castillo,-JR	12		Anal. Spectroscopy and Sensors Group, Dept. Anal. Chem., Univ. Zaragoza, Zaragoza, Spain
Li,-Y	12		Vaccine Bioprocessing Div., Merck and Co. Inc., West Point, PA 19486, USA
Araujo,-AN	12		REQUIMTE/Dept. Quim.-Fis., Fac. Farmacia, Univ. Porto, 4099-030 Porto, Portugal
Molina-Diaz,-A	11		Dept. Phys. and Anal. Chem., Fac. Experimental Sci., Univ. Jaen, 23071 Jaen, Spain
Jiang,-GB	11		Res. Eco-Environ. Sci., Chinese Acad. Sci., Beijing 100085, China
Liu,-JF	11	With Jiang GB	Res. Center Eco-Environ. Sci., Chinese Acad. Sci., Beijing 100085, China
Rondon,-C	11	With Burguera	Fac. Ciencias, IVAIQUIM, Univ. Los Andes, Merida 5101-A, Venezuela
Cardenas,-S	11	With Valcárcel M	Dept. Anal. Chem., Univ. Cordoba, 14071 Cordoba, Spain

(*continued*)

Table 1. Continued

Author	Number of papers	Co-workers	Institution
Medina,-AR	11	With Molina Diaz A	Dept. Phys. and Anal. Chem., Fac. Experimental Sci., Univ. Jaen, 23071 Jaen, Spain
Ruzicka,-J	10		Dept. Chem., Univ. Washington, Seattle, WA 98195-1700, USA
Ensafi,-AA	10		Coll. Chem., Isfahan Univ. Technol., Isfahan 84154, Iran
Jin,-QH	10		Inst. Anal. Sci., Jilin Univ., Changchun 130023, China
Zachariadis,-GA	10	With Stratis JA	Lab. Anal. Chem., Dept. Chem., Aristotle Univ., Thessaloniki 54124, Greece
Oguma,-K	10		Dept. Materials Technol., Fac. Eng., Chiba Univ., Chiba 263-8522, Japan
Carrero,-P	10	With Burguera	Venezuelan Andean Inst. Chem. Res. (IVAIQUIM), Fac. Sci., Univ. Los Andes, Merida 5101-A, Venezuela
Combs,-RJ	10	With Small GW	Center Intelligent Chem. Instrumentation, Clippinger Lab., Ohio Univ., Athens, OH 45701-2979, USA
Armenta, -S	9	With de la Guardia M	Dept. Quim. Anal., Univ. Valencia, 46100 Burjassot, Valencia, Spain
Adams,-FC	9		Dept. Chem., Micro and Trace Anal. Center (MiTAC), Univ. Instelling Antwerp, 2610 Antwerp, Belgium
Hirano,-Y	9	With Oguma K	Dept. Materials Technol., Fac. Eng., Chiba Univ., Yayoi-cho, Inage, Chiba 263-8522, Japan
Hirata,-S	9		Inst. Marine Resources and Environ., Natl. Inst. Adv. Ind. Sci. and Technol. (AIST), 737-0197 Kure, Japan
Infante,-HG	9	With Adams FC	Dept. Chem., Micro and Trace Anal. Center (MiTAC), Univ. Instelling Antwerp, 2610 Antwerp, Belgium
Sakai,-T	9		Dept. Applied Chem., Aichi Inst. Technol., Aichi 470-0392, Japan

(*continued*)

Table 1. Continued

Author	Number of papers	Co-workers	Institution
Kroutil,-RT	9	With Small GW	Dept. Chem. and Biochem., Center Intelligent Chem. Instrumentation, Clippinger Lab., Ohio Univ., Athens, OH 45701-2979, USA
Salvador,-A	9		Dept. Quim. Anal., Fac. Quim., Univ. Valencia, 46100 Burjassot, Valencia, Spain
Santelli,-RE	9		Dept. Geoquim., Univ. Fed. Fluminense, Niteroli 24020-007, Brazil
Cassella,-RJ	9		Centro Fed. Educacao Tecnol. Quim.-RJ, Rio de Janeiro, RJ 20270-021, Brazil
Worsfold,-PJ	9		Dept. Environ. Sci., Plymouth Environ. Res. Centre, Univ. Plymouth, Plymouth PL4 8AA, UK
Zhang,-ZQ	9		School Chem. and Materials Sci., Shaanxi Normal Univ., Xi'an 710062, China
Yang,-L	9	With He YZ	Coll. Chem., Xiangtan Univ., Xiangtan 411105, China
Silva,-MF	9	With Martinez LD	Dept. Anal. Chem., Fac. Chem., Biochem. and Pharm., Natl. Univ. San Luis, 5700 San Luis, Argentina
Watanabe,-K	9		Dept. Environ. Sci., Japan Atomic Energy Res. Inst., Ibaraki 319-1195, Japan
Zhang,-HQ	9		Dept. Chem., Jilin Univ., Changchun 130023, China
Itagaki,-M	9		Dept. Pure and Applied Chem., Fac. Sci. and Technol., Tokyo Univ. Sci., Chiba 278-8510, Japan
Stefan,-RI	8		Dept. Chem., Univ. Pretoria, Pretoria 0002, South Africa
Berndt,-H	8		Inst. Spektrochem. und Angewandte Spektroskopie (ISAS), 44139 Dortmund, Germany
Fatibello,-O,-filho	8		Dept. Quim., Centro Cien. Exatas e Tecnol., Univ. Fed. Sao Carlos, 13.560-970 Sao Carlos, Brazil
He,-YZ	8		Dept. Chem., Univ. Sci. and Technol. China, Hefei 230026, China

(*continued*)

Table 1. Continued

Author	Number of papers	Co-workers	Institution
Kim,-CK	8		Dept. Radiol. Safety Res., Korea Inst. Nuclear Safety, Taejon 305-338, South Korea
Lang,-HY	8		Dept. Chem., Northwest Univ., Xi'an 710069, China
Masini,-JC	8		Inst. Quim., Univ. Sao Paulo, 05513-970 Sao Paulo, Brazil
Wu,-JC	8	With Pawliszyn J	Dept. Chem., Univ. Waterloo, Waterloo, ON N2L 3G1, Canada
Ivanova,-E	8	With Adams FC	Micro-Trace Anal. Centre, Dept. Chem., Univ. Antwerp, 2610 Antwerp, Belgium
Xu,-SK	8		Res. Center Anal. Sci., Northeastern Univ., 110004 Shenyang, China
Beauchemin,-D	8		Dept. Chem., Queen's Univ., Kingston, ON K7L 3N6, Canada
Carasek,-E	8		Dept. Quim., Univ. Fed. Santa Catarina, Florianopolis SC 88040-900, Brazil
Ye,-CL	8		Key Lab. Env. Sci. and Eng. Henan Education Dept., School Chem. and Env. Sci., Henan Normal Univ., Xinxiang 453002, China
de-Wuilloud,-JCA	8	With Martinez LD	Area Quim. Anal., Fac. Quim., Bioquim. Pharm., Univ.Natl. San Luis, Chacabuco y Pedernera, 5700 San Luis, Argentina
Bendicho,-C	8		Dept. Quim. Analitica y Alimentaria, Area Quim. Analitica, Facultad Ciencias (Quimica), Universidad Vigo, 36200 Vigo, Spain
Henion,-J	8		Anal. Toxicol., Dept. Population Med. and Diagnostic Sci., Cornell Univ., Ithaca, NY 14850, USA
Lavilla,-I	8	With Bendicho C	Dept. Quim. Analitica y Alimentaria, Area Quim. Analitica, Facultad Ciencias (Quimica), Universidad Vigo, 36200 Vigo, Spain
Quintás, -G	7	With de la Guardia M	Dept. Quim. Anal., Univ. Valencia, 46100 Burjassot, Valencia, Spain

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Table 1. Continued

Author	Number of papers	Co-workers	Institution
Camara,-C	7		Dept. Quim. Anal., Fac. Ciencias. Quim., Univ. Complutense Madrid, 28040 Madrid, Spain
Cervera,-ML	7	With de la Guardia M	Dept. Anal. Chem., Fac. Chem., Univ. Valencia, 46100 Burjassot, Valencia, Spain
Cladera,-A	7	With Cerdá V	Dept. Chem., Fac. Sci., Univ. Balearic Islands, 07122 Palma de Mallorca, Spain
Focant,-J-F	7		Mass Spectrometry Lab., Dioxin Lab., Univ. Liege, 4000 Liege, Belgium
Gonzalez-Revalderia,-J	7		Servicio Bioquim., Hospital Univ. Getafe, 28905 Madrid, Spain
Jin,-ZX	7		Coll. Chem. and Environ. Eng., Jianghan Univ., Wuhan 430019, China
Ruiz-Medina,-A	7	With Molina Diaz A	Dept. Phys. and Anal. Chem., Fac. Experimental Sci., Univ. Jaen, 23071 Jaen, Spain
Salonia,-JA	7	With Martinez LD	Dept. Anal. Chem., Fac. Chem., Biochem. and Pharm., Natl. Univ. San Luis, 5700 San Luis, Argentina
Sun,-HW	7		Key Lab. Anal. Sci. and Technol., Hebei Province Coll. Chem. and Environ. Sci., Hebei Univ., Baoding 071002, China
Wang,-XR	7		Key Lab. Anal. Sci. Ministry Education China, Xiamen Univ., Xiamen 361005, China
Zenki,-M	7		Dept. Chem., Fac. Sci., Okayama Univ. Sci., Okayama 700-0005, Japan
Zhang,-L	7		Centre Intelligent Chem. Instrumentation, Dept. Chem. and Biochem., Ohio Univ., Athens, OH 45701, USA
Cespon,-RM	7	With Yebra MC	Dept. Anal. Chem., Univ. Santiago Compostela, 15782 Santiago Compostela, Spain

(*continued*)

Table 1. Continued

Author	Number of papers	Co-workers	Institution
Baena,-JR	6	With Lendl B	Inst. Chem. Technol. and Anal., Vienna Univ. Technol., 1060 Vienna, Austria
Bakhtiar,-R	6		Merck and Co., Rahway, NJ 07065, USA
Cardwell,-TJ	6		Anal. Chem. Lab., Dept. Chem., La Trobe Univ., Bundoora, Vic. 3086, Australia
Catala-Icardo,-M	6	With Martinez Calatayud J	Dept. Anal. Chem., Univ. Valencia, Valencia 46100, Spain
Cattrall,-RW	6	With Kolev SD	School Chem., Univ. Melbourne, Parkville, Vic. 3010, Australia
Chen,-YH	6		School Chem. and Environ. Sci., Henan Normal Univ., Henan 453002, China
Chisvert,-A	6	With Salvador A	Dept. Quim. Anal., Fac. Quim., Univ. Valencia, 46100 Valencia, Spain
Gan,-WE	6	With He YZ	Dept. Chem., Univ. Sci. and Technol. China, Hefei 230026, China
Garcia-Campana,-AM	6		Dept. Anal. Chem., School Qualimetrics, Univ. Granada, 18071 Granada, Spain
Garcia-Mateo,-JV	6	With Martinez Calatayud J	Dept. Ciencias Quim., Fac. Ciencias Exp. y Salud, Univ. Cardenal Herrera C.E.U., Valencia 46113, Spain
Guo,-XM	6		Inst. Natl. Measurement Standards, Natl. Res. Council Canada, Ottawa K1A 0R6, Canada
Kawashima,-T	6		Lab. Anal. Chem., Dept. Chem., Univ. Tsukuba, Tsukuba 305-8571, Japan
Knapp,-RB	6	With Small GW	Dept. Chem. and Biochem., Center Intelligent Chem. Instrumentation, Ohio Univ., Athens OH 45701-2979, USA
Kolev,-SD	6		School Chem., Univ. Melbourne, Parkville, Vic. 3010, Australia
McKelvie,-ID	6	With Kolev SD	Water Studies Centre, School Chem., Monash Univ., Clayton, Vic. 3800, Australia

(*continued*)

Table 1. Continued

Author	Number of papers	Co-workers	Institution
Montenegro,-MCBSM	6		Environ. and Quality Eng. Lab., Chem. Eng. Dept., UFPE, 50740-521 Recife
Nakayama,-H	6		Integrated Proteomics System Project, Tokyo Metropolitan Univ., Tokyo 192-0397, Japan
Perez-Juan,-P	6	With Luque de Castro MD	Anal. Chem. Div., Fac. Sci., Univ. Cordoba, 14004 Cordoba, Spain
Popp,-P	6		Dept. Anal. Chem., UFZ Centre Environ. Res., 04318 Leipzig, Germany
Santos,-JLM	6	With Lima JLFC	Requimte/Dept. Quim.-Fis., Fac. Farmacia, Univ. Porto, 4050-047 Porto, Portugal
Vereda-Alonso,-E	6	With Cano Pavon JM	Fac. Sci., Univ. Malaga, 29071 Malaga, Spain
Zhuang,-ZX	6		Coll. Bioeng., Jimei Univ., Xiamen 361021, China

order to reduce waste generation and reagent and sample consumption and to improve the analytical figures of merit and laboratory productivity.

As can be seen in Fig. 4, the number of applications of automated or mechanized procedures in the field of spectroscopy has grown exponentially to reach maturity in this century.

Automated developments have been applied to atomic and vibrational spectrometries, molecular techniques, and chromatography-based studies using spectrometric detectors. As can be seen in Fig. 4, atomic studies provide the most studied systems, with a percentage of 41.1%, in the application of automation or mechanization. Chromatography with spectrometric detection, UV-visible techniques, and infra-red constitute 30.8%, 18.8%, and 9.3% of the published papers in this century, respectively.

Automation improves spectrometric measurements through (i) fast sampling and cleaning of the measurement cells, (ii) fast analytical control of the spectral baseline, (iii) an easy and rapid standardization, (iv) improved repeatability, (v) a considerable reduction of reagent, solvent consumption, and waste generation, and (vi) a possible enhancement of the analytical sensitivity through the online coupling of spectrometric detection with preconcentration techniques.

So, it is evident that advances in flow and automation have been important in the improvement of all the aforementioned spectrometric techniques.

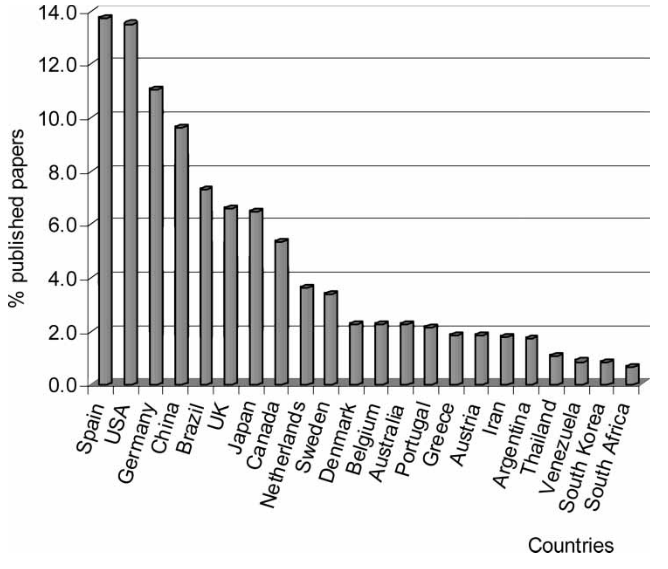

Figure 3. Geographical distribution of authors of the literature published on automation and spectroscopy. (Source: *Anal. Abstr.* 2000–2006.)

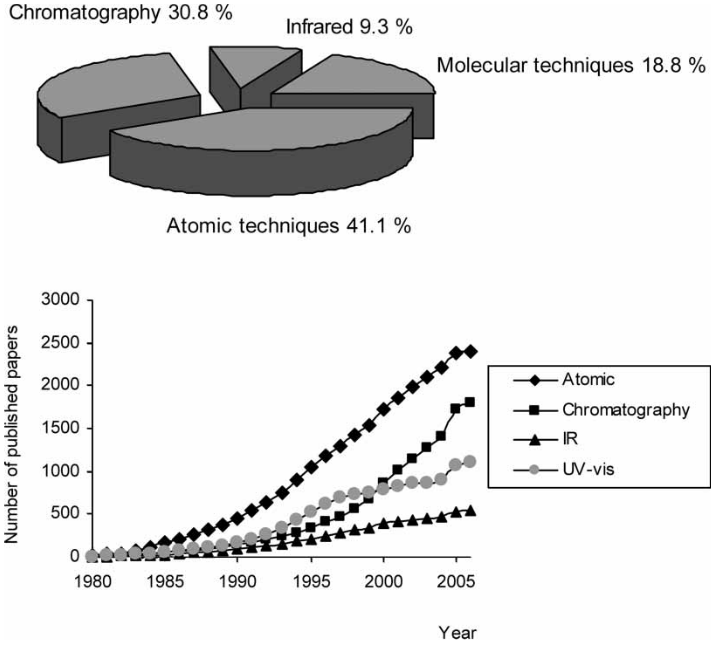

Figure 4. Evolution and distribution of the literature on automation and spectroscopy for different analytical techniques. (Source: *Anal. Abstr.* 2000–2006.)

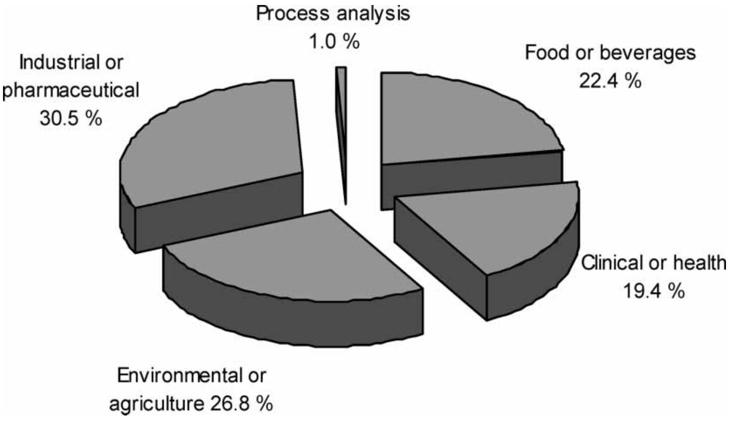

Figure 5. Distribution of the literature published on automation and spectroscopy as a function of the different application fields. (Source: *Anal. Abstr.* 2000–2006.)

APPLICATION FIELDS OF AUTOMATION AND SPECTROSCOPY

Figure 5 shows the fields of application of automated spectroscopy studies, considering the type of samples analyzed. It is clear that industrial pharmaceutical samples are those to which the main part of studies were devoted (30.5%), followed by environmental or agriculture, food or beverages, and clinical or health fields, with percentages of 26.8%, 22.4%, and 19.4%, respectively.

It must be noticed that the aforementioned distribution remains practically unchanged during the past few years. However, it must be observed that there is increasing interest in process analysis, which nowadays only represents 1% of the automation and spectroscopy studies.

FUTURE PERSPECTIVES

From the literature published till today, it can be concluded that automation and spectroscopy is a good marriage and highly productive and is a well-established practice in research laboratories.

The advances in the field of flow components like micropumps or pinch valves will clearly improve the manifolds but also provide a miniaturization of the systems, together with the possibility to develop low-cost devices with reduced power consumption, which are useful for online monitoring of both environmental parameters and industrial processes. So, we hope that the next decade will be that of fully integrated approaches involving all the analytical steps, from sampling to data treatment through the use of automated devices with a low-energy power supply, and possibilities of automated data transfer through the Internet.

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