

European Survey for Chemists

The Professional Status of European Chemists and Chemical Engineers

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Abstract: Which country pays its chemists and chemical engineers the highest salaries? Where can I find a new job quickest? Which chemical sub-discipline offers most jobs? Reliable answers for these and other questions have been

derived from the first European employment survey for chemists and chemical engineers, which was carried out in 2013. Here we publish the first general evaluation of the results of this survey.

The development of the questionnaire and the data collection was commissioned by the Joint Research Centre (JRC) of the European Commission and executed by the European Chemistry Thematic Network Association (ECTN). It was strongly supported by the European Association for Chemical and Molecular Sciences (EuCheMS), the European Chemical Industry Council (Cefic), and the European Chemistry and Chemical Engineering Education Network (EC2E2N2). Participating National Societies (member societies of EuCheMS) cover more than 90% of the EuCheMS membership. Each participating society nominated a National Delegate, who was responsible for supporting the survey within each participating National Society.

The American Chemical Society (ACS) regularly publishes an employment survey in *Chemical & Engineering News* (see Ref. [1] for the most recent report). Data were collected from ACS members working within the USA. The ACS survey focuses on salary and employment. The survey results clearly show in which sub-discipline the graduates received their highest qualification and in which sub-discipline they are working after

starting their professional careers. It would be of utmost interest for decisions within Europe to have access to similar data.

The ACS survey and the European Employment Survey have similar objectives. Several other surveys or reports have been published that focus on educational issues. Examples are surveys by the Austrian Chemical Society^[2] or by the Royal Society of Chemistry.^[3] The importance of physics to the economies of Europe was investigated by the European Physical Society.^[4] The International Society for Optics and Photonics (SPIE) publishes its Optics & Photonics Global Salary Reports with major contributions from North America, Europe, and Asia (see Ref. [5] for the most recent report).

1. Survey: Participation, Questionnaire, Evaluation

A total of 4440 chemists and chemical engineers responded to the first issue of the European Employment Survey. This report does not differentiate between chemists and chemical engineers, and their responses have been evaluated jointly. For convenience, in this Editorial this joint group of chemists and chemical engineers will simply be referred to as “chemists”.

A rigid procedure was developed and applied to purge the responses of irregular answers. 3830 responses remained after this process and these were evaluated further. Particular emphasis was placed on the employment situation of chemists who graduated within the last 15 years, and 2445 responses came from chemists fitting this criterion. All responses were stored in anonymous form.

The questionnaire had six general sections (Personal : Education : Employment : Job : Training : Salary), which provided fields for free-text responses. Industry employees were asked special questions in an additional section. The participation of industry employees accounted for 47% of the responses. This group covered manufacturing industry, non-manufacturing industry, self-employed chemists, and publishing houses.

The age of the responders exhibits a distinct maximum around 30 years of age (Figure 1). The youngest responders

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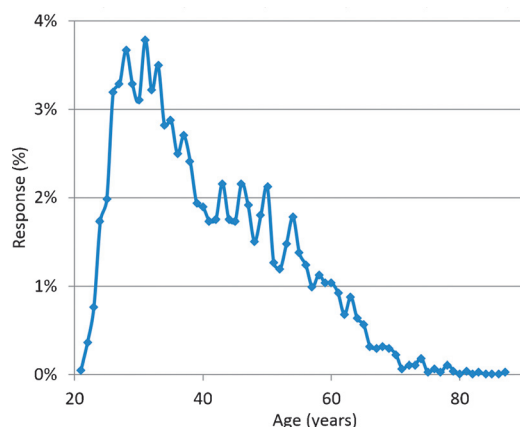


Figure 1. Percentage of responses for all ages.

were aged 20 and the most experienced one was 87 years old. Pensioners submitted 2% of all responses, students 5%. Only 3% of all responders were not employed or were seeking employment. The overwhelming contribution (90% of all responses) came from colleagues having either a full-time or a part-time job. A partial evaluation focussing on analytical chemistry has already been published.^[6]

The results of a cross evaluation might be dominated by the large share of responders from Italy and the UK (cf. Figure 2) and several conclusions could be heavily biased. Accordingly, this called for an evaluation of individual countries together with the joint evaluation of all European responses. Spain is the last of 10 countries in Figure 2 with more than 100 re-

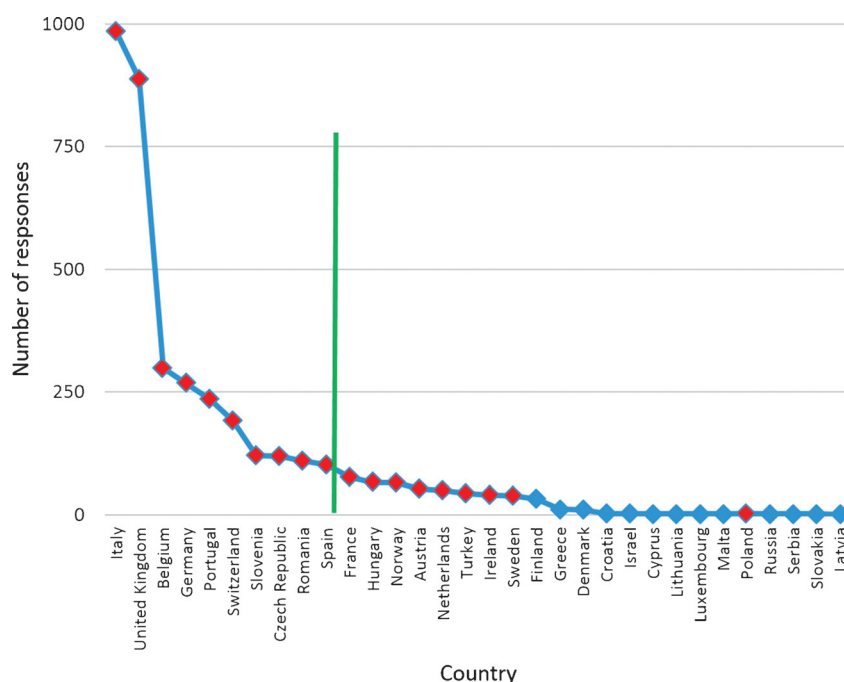


Figure 2. Absolute number of responses from countries. Data points in red indicate responses from countries with national society/societies participating in the survey. Data points in blue indicate countries, from where responses were obtained but whose national society did not participate in the survey. Each country to the left of the green parting line submitted more than 100 responses.

sponses. For statistical reasons only the 10 countries with more than 100 responses were evaluated individually. This country-specific evaluation should clearly reveal differences in traditions and/or conditions between various European countries.

The questionnaire was offered in 24 European languages: Bulgarian, Czech, Danish, Dutch, English, Estonian, Finnish, French, German, Greek, Hungarian, Irish, Italian, Latvian, Lithuanian, Norwegian, Polish, Portuguese, Romanian, Slovakian, Slovenian, Spanish, Swedish and Turkish. Six of the offered languages were not used: Bulgarian, Danish, Estonian, Irish, Lithuanian, Slovakian. Responses from some of these countries were submitted in English and a number of chemists preferred to respond in English instead of their native language. Apart from UK with its particular language situation, the largest preference for English was found for Switzerland (Figure 3). 59% of all Swiss responses were in English, even though the three most used official Swiss languages were available.

Responses were also received from the following non-EU countries: Switzerland, Norway, Turkey, Israel, Russia, and Serbia (ordered according to the number of responses). Chemical societies of all of these countries are members of EuCheMS.

The total share of women in the survey was 39%, but there are significant differences between countries. Southern and Eastern European countries are well above average (Figure 4). In comparison, the last ACS report^[7] shows a participation of 30% women (full-time employed). The percentage of women relative to men in the US chemical workforce was 21% in 1995 and 26% in 2007.^[8]

2. Education

Of those who responded to the survey, almost 20% of all graduates of the last 15 years chose chemical engineering as the chemical discipline for their highest qualification (Figure 5). Organic chemistry and analytical chemistry came in second and third. In comparison, the ACS survey was dominated by organic chemistry;^[9] analytical chemistry ranked second with about half the share of organic chemistry, closely followed by physical chemistry and general chemistry.

The picture in the ACS survey of 2013 graduates^[10] was surprisingly different from the results for all ages mentioned above. Almost half of all 2013 graduates obtained their highest degree in general chemistry. A third chose biochemistry. According to the 2013 graduates survey, 85% of the responders

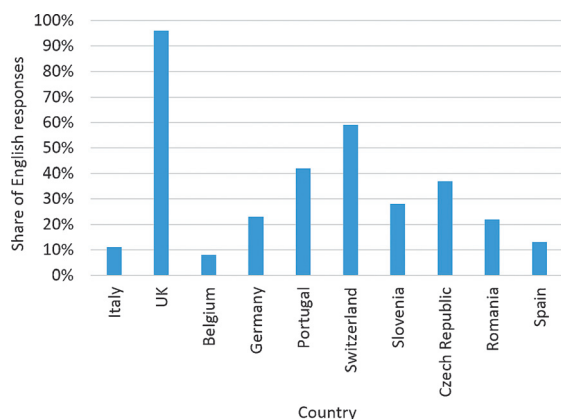


Figure 3. Use of English instead of the available national language in the 10 countries.

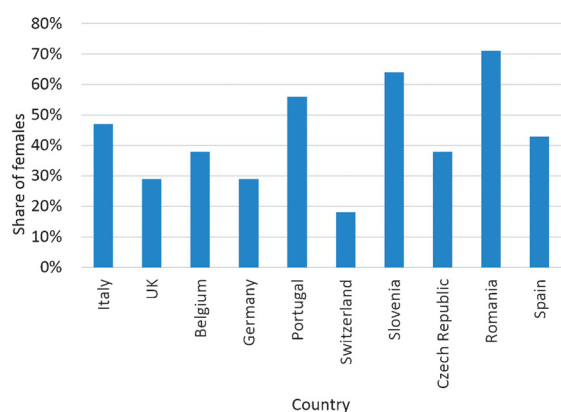


Figure 4. Share of women in the chemistry workforce of the 10 most responding European countries.

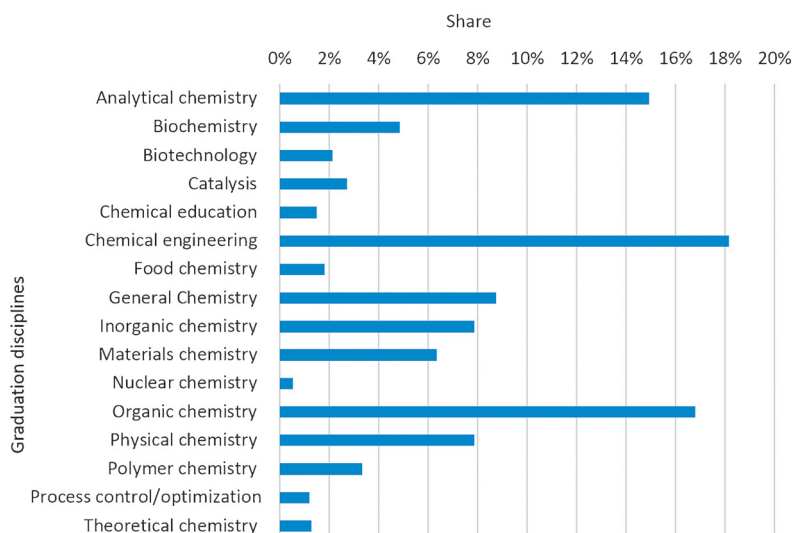


Figure 5. Graduation disciplines of the highest qualification in Europe (graduation within the last 15 years).

obtained new Bachelor's degrees, and most of them continued studies in a field other than chemistry.

The distribution of graduation disciplines differ significantly between European countries (Figure 6). Moreover, none of the European countries has a distribution of graduation disciplines

similar to the USA. Chemical engineering clearly dominates in Spain and Portugal, organic chemistry in Switzerland, general chemistry in the UK, analytical chemistry in Italy, and biochemistry in Belgium.

The distribution of graduation disciplines not only differs significantly between countries but also between employment sectors (Figure 7). The top employer for analytical chemists is government/public service. Most jobs for chemical engineers are located in industry, both in manufacturing and non-manufacturing. Research institutions predominantly hire organic chemists and analytical chemists. The graduation profile of employees in higher education mirrors quite well the education profile of these institutions (Figure 5).

The distribution of graduation disciplines with respect to industry sectors (Figure 8) shows the following relations: the two dominating graduation disciplines of employees in the industry sector chemicals are chemical engineering and organic chemistry, thereafter come general chemistry and analytical chemistry some way behind. Many jobs for chemists are also available in the healthcare industry sector, but the total number of responders from healthcare industry is merely one third of that from the chemicals sector. The largest groups of employees in the healthcare industry graduated in organic chemistry, in general chemistry, and in analytical chemistry. Apart from the chemicals sector, chemical engineers find jobs in many industry sectors. The only exception is the biotechnology sector, which offers distinctly less jobs for chemical engineers than any other industry sector. Jobs for chemical engineers are much more evenly distributed than for graduates of any other chemical discipline. Analytical chemists find a significant number of jobs in many industry sectors outside chemicals as well, but not as widely spread as in the case of chemical engineering.

Based on the responses, the most frequently acquired degree in Europe is the doctoral degree (44%), followed by the Master's degree (38%) and the Bachelor's degree (12%) and the Habilitation (higher doctorate) (5%, Figure 9). Less than 1% of all responders hold a post-secondary or a short-cycle degree. Because of the small number of responses, the latter group could not be evaluated further. Compared to ACS surveys, the first three degree levels are calculated on a slightly different basis, but the ratios can be compared with the results reported here. The ACS values for 2013 are Ph.D. 67%,

Master's 16%, Bachelor's 17%^[11]. The ACS report also reveals a continuous shift towards the Ph.D. degree since 1995. The ratio in 1995 was Ph.D. 59%, Master's 17%, Bachelor's 24%. In European Higher Education, the Bachelor's degree is of somewhat lower importance than in the US job market. The Mas-

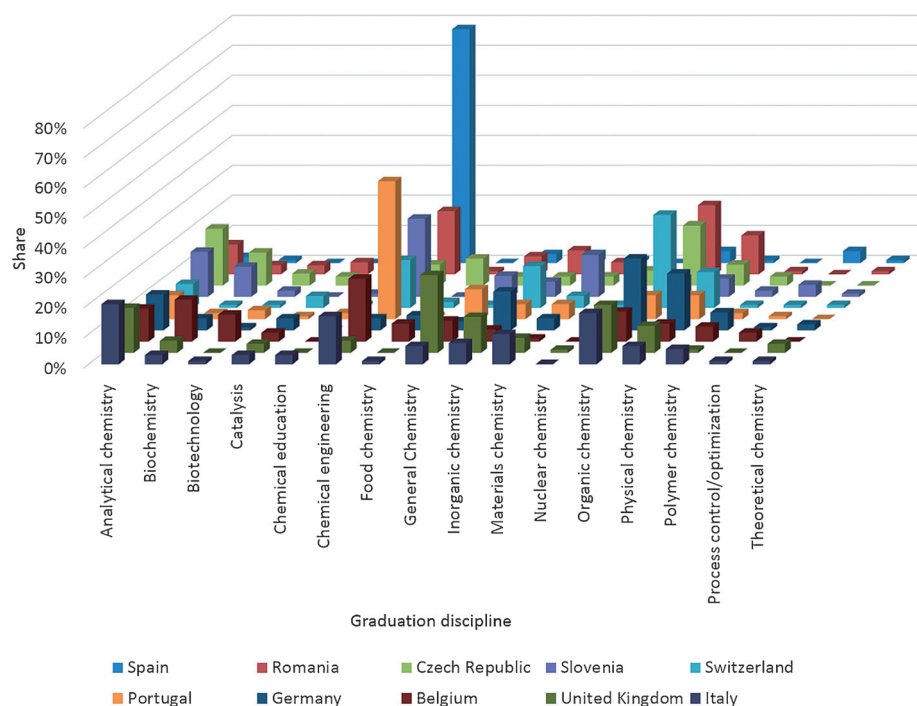


Figure 6. Shares of graduation disciplines vary significantly between countries (graduation within the last 15 years). Percentages refer to the total number of graduates within each country.

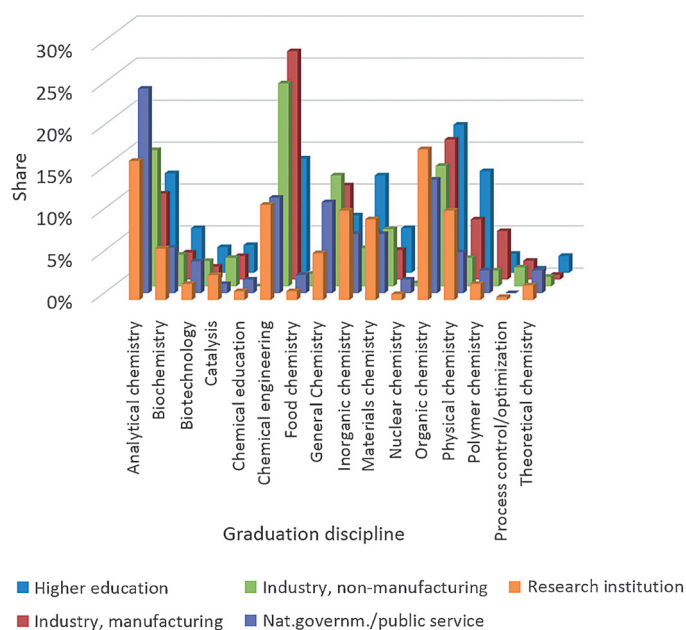


Figure 7. Distribution of graduation disciplines within employer sectors (graduation within last 15 years). Percentages refer to the total number of graduates per employer sector. Publishing companies, secondary schools, self-employed, and vocational schools omitted because of insufficient data.

ter's degree has a significantly higher importance (and academic value) in Europe. Even if the number of chemists holding a Habilitation and Ph.D are summed up for Europe, their share in the chemical workforce is less than the corresponding share of Ph.D. holders in the US chemical workforce.

The target qualification differs very much between chemical disciplines (Figure 10). More than half of all responders who obtained their highest qualification in general chemistry hold a Bachelor's degree. In clear contrast, in food chemistry and nuclear chemistry only 10% hold a Bachelor's degree. The highest share of Master's degree is found in chemical engineering and process control & optimization, whereas less than 10% of the graduates in general chemistry hold a Master's degree. The dominating qualification in nuclear chemistry is a Ph.D. (60%), followed by a group with around 40% (food chemistry, inorganic chemistry, organic chemistry, physical chemistry, theoretical chemistry). The outright leader at the Habilitation level is chemical education (18%) for obvious reasons.

3. First Job

The vast majority of all responders (77%) found their first job immediately after graduation. Approximately one third of all responders started their professional career with a permanent contract, another third with a temporary contract (Table 1).

The share of the graduates of the last 15 years who did not get their first job immediately after graduation varied very much between countries (Figure 11). With respect to the current economic situation the results are perhaps not surprising with the highest shares for Italy (28%), Portugal (21%), and Spain (20%). On the other hand, Germany follows closely at 19%, whereas all Hungarian graduates and 99% of the Romanian graduates found a job immediately. The picture is obviously very complex and does not permit a simple explanation.

How does the chosen graduation discipline influence employability (Figure 12)? If we look again at the share of graduates not getting their first job immediately after graduation, the three dominating graduation disciplines—chemical engi-

Table 1. Contracts for the first job after graduation (all responses).

Contract	[%]
Permanent	34
Temporary	35
Apprenticeship	5
Undergraduate study	0.6
Graduate study	11
Postdoctoral research	11
no data submitted	4

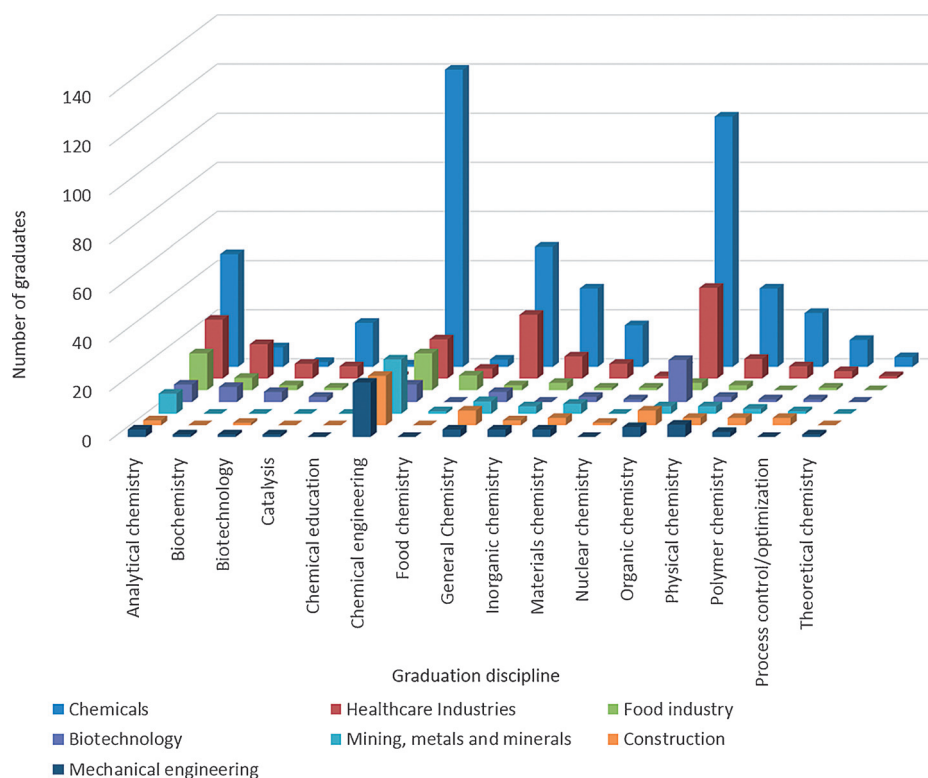


Figure 8. Shares of graduation disciplines within industry sectors of greatest importance for chemists (graduation within the last 15 years). Absolute numbers of graduates are given in order to highlight the importance of the particular industry sector for employment of chemists.

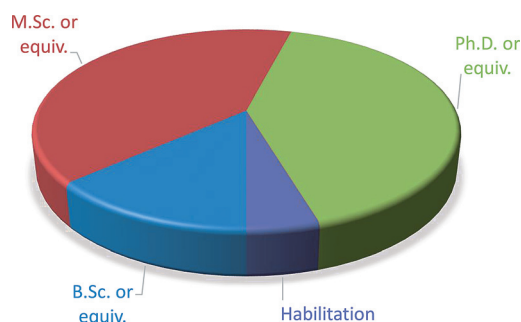


Figure 9. Highest academic degrees acquired in the European chemical workforce.

neering, organic chemistry, analytical chemistry—are found at medium shares. The situation is slightly more difficult for graduates of process control and optimization, materials chemistry, and polymer chemistry.

The share of graduates of the last 15 years not getting their first job immediately varied over time (Figure 13). Absolute numbers of responses behind the percentage values in Figure 13 vary between 43 for 2010 and 16 for 1998. Shares above 20% are found for the years 1999 and 2009/2010. Shares between 16% and 13% were reported by graduates for the years 1998, 2001, 2007, and 2013. These results do not seem to be related to any economic development in Europe during the investigated years.

We also asked about the number of months needed to find the first job. It turned out that the vast majority of the job seekers reported exactly six months. The detailed analysis of the medium number of months for a job search with respect to graduation discipline or country predominantly gave six months. The few exceptions with shorter search time are the graduation disciplines nuclear chemistry, theoretical chemistry, and catalysis. With respect to location, the exceptions with a slightly longer search time of eight months are Norway, Ireland, Czech Republic, whereas only three months were usually required in Sweden, Romania, and Austria.

4. Working Countries, Contracts, Satisfaction

A total of 86% of all responders work in their native country. In order to compare the situation for the 10 countries for which we have received most responses,

the share of native workers was related to the number of responses from this particular country. The share of native workers fluctuates between 80% (Germany) and 99% (Romania) with one clear exception: Switzerland is the native country for only 41% of its chemists and chemical engineers (Figure 14). This large proportion of non-native workers relates very well to the Swiss preference for English language in the questionnaire (cf. Figure 3). Moreover, there is a slight coincidence between larger shares of females in the workforce (Figure 4) and the extent of native workers in a particular country. Apparently, women are tighter bound to their native region than men.

As can be expected, the median age raises with graduation level, but there is an exception with elevated age at Bachelor's degree (Table 2). It is also evident that the share of females decreases towards higher graduation levels. As to mobility, more Bachelors remain in their native country; most mobile are holders of a doctoral degree.

It was interesting to compare the graduation degrees of the complete workforce with respect to age, gender, and location of employment for the graduates of 2013 (Table 3). The number of responses from the graduates of 2013 was 164. The most frequently acquired degree in 2013 was the Master's degree (48%), followed by the doctoral degree (34%), the Bachelor's degree (13%), and the Habilitation (higher doctorate, 3%). Less than 1% of all responders hold a post-secondary or a short-cycle degree. Compared to the chemistry workforce

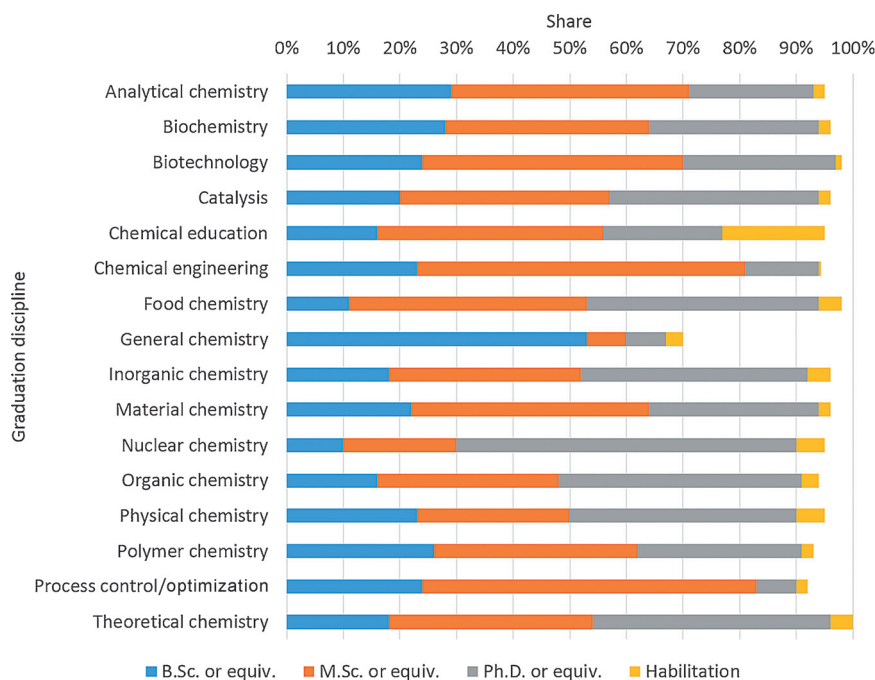


Figure 10. Varying share of most frequent qualifications within graduation disciplines (all accepted responses). Percentages refer to the total number of graduates per graduation discipline. Not shown due to insufficient number of data are the following qualifications: post-secondary, short-cycle tertiary, other qualification.

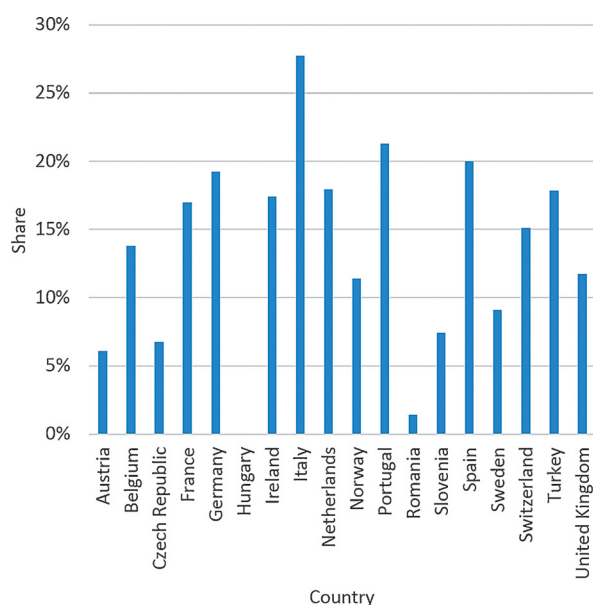


Figure 11. Percentage of graduates of various countries not getting the first job immediately after graduation (graduation within the last 15 years, only countries with > 20 entries).

of all ages (Figure 9), significant differences are found for Master's degree (+10%) and doctoral degree (−10%). However, some of the current holders of a Master's degree will certainly continue and acquire a doctoral degree. Table 3 points to a larger share of women at higher qualification levels. There is also a certain indication of increased mobility among the younger graduates.

We double-checked the share of women at higher graduation levels for the graduates of 2009. For this year, we received 112 responses from M.Sc. graduates; 38% of whom are women. At Ph.D. level we got 56 responses, 48% of whom are women. These data support the tendency towards larger shares of women at higher graduation levels in more recent times.

The situation of the graduates of 2009 was reviewed in an ACS survey^[12] and can be compared to the current situation of graduates in Europe (Table 3). The ACS survey reports the following median ages: B.Sc./B.A. 22 years; M.Sc. 27 years; Ph.D. 30 years. The share of women is: B.Sc./B.A. 55%; M.Sc. 48%; Ph.D. 39%. This indicates a distinct difference: the share of women in the European chemical workforce rises towards

higher qualification levels, whereas it clearly drops in the ACS membership.

The majority of non-native workers maintained their citizenship of another EU country (56%); many hold residence permits (permanent 16%, fixed-term 13%). Only 8% of the non-native workers decided for naturalization.

Of all chemists, 68% have a permanent contract, only 14% a temporary contract (Figure 15). An apprenticeship is not common among chemistry employees. Only 1% of all responders hold an apprenticeship contract, most of them in Italy and most of them hold a Master's degree. Participation of undergraduate students in the survey was extremely low (0.1%). 7% of all responders are graduate students, 5% Postdoctoral researchers. Of those with a permanent contract, 96% work full-time and 4% work part-time. Of those with a temporary contract, 80% work full-time and 20% work part-time.

The gender distribution of those with a permanent contract is in agreement with the conventional expectations: 65% of the employees working full-time are males, 67% of the employees working part-time are females. In case of temporary contracts, females and males participate equally both for full-time and for part-time contracts.

The overwhelming majority of chemists in Europe work full-time (85%). Only 6% work part-time (Figure 16), and only 3% of all responders are not employed or seeking employment. This low number might be an indication that the survey did not reach unemployed chemists well. In the ACS survey of 2013, the following values are reported: 91% work full-time, 3% part-time, 3% are Postdoctoral researchers, and 4% are seeking employment.^[13]

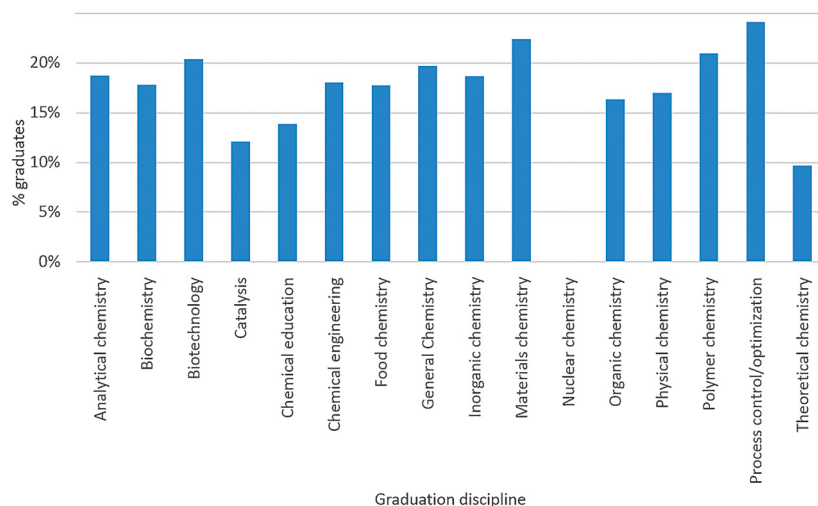


Figure 12. Percentage of graduates of the different graduation disciplines not getting the first job immediately after graduation (graduation within the last 15 years).

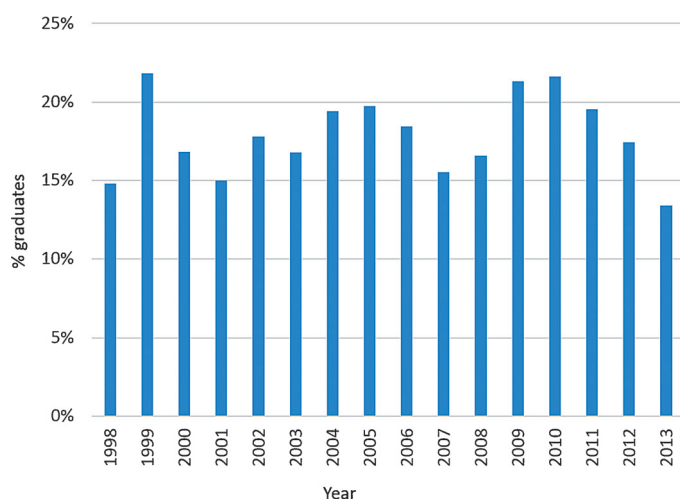


Figure 13. Percentage of graduates not getting the first job immediately after graduation (graduation within the last 15 years, only countries with > 20 entries).

With the vast majority of chemists in Europe having a permanent contract and working full-time, we investigated job satisfaction (Figure 17). The response had two positive options (very much/yes) and two more or less negative options (somewhat/not at all). The outcome is very positive (between 75% and 80%) with respect to the relation of the job to the field, to the training, and whether it is challenging. In contrast, for only 56% of chemists does the job fit the expectations, and 17% of all chemists even think that their job does not fit their expectations at all. There seems to be a large gap between the image of chemistry as it is portrayed in the early years of education and the real professional world.

5: Jobs: Employer Sector, Industry Sectors, Requested Qualification, Job Function

The dominating employer sector for chemists in Europe is the manufacturing industry (Figure 18); 32% of all responders work there. Research institutes provide 19% of all jobs for chemists and rank second. Research institutes are closely followed by higher education institutions, which employ 17% of all responders. 8% of all chemists work in other government or public service positions. Shares of self-employed (3%), chemists in secondary schools (2%), publishing companies (2%), and vocational schools (0.1%) are small. It should be noted that in some countries curricula for school teachers and chemists differ significantly, school teachers may even have their own organisations. From such countries we received only few or even (like for Germany) no response.

The importance of employer sectors for the job market for chemists varies significantly between European countries. Such variations are a result of the rich cultural and economic heritage in Europe. The data in Figure 19 reveal the importance of the employer sectors for individual countries. The percent values relate the number of jobs to the number of responses from this particular country. This means, for example, the top value in the graph (47% share for higher education in Romania) indicates the dominating role of this sector for the particular country. It does not mean that the number of positions for

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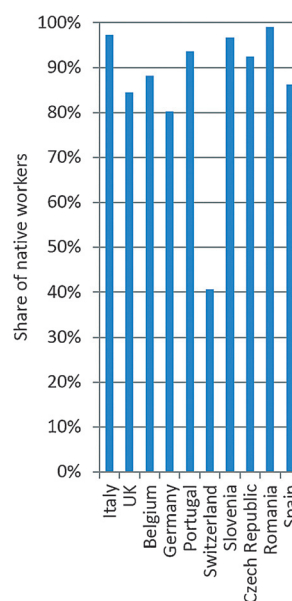


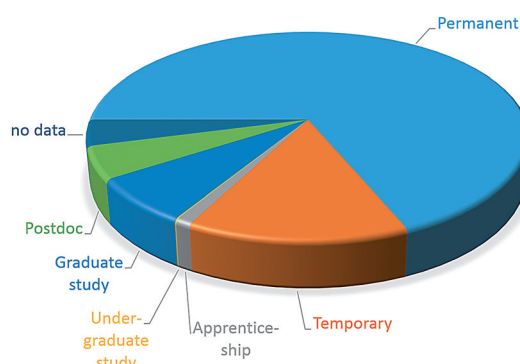
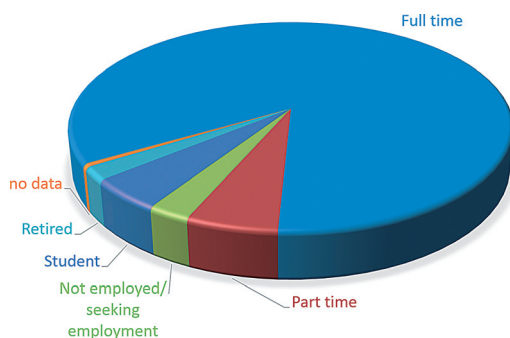
Figure 14. Share of responders working in their native country.

Table 2. Median age, share of females and native workers for the four major graduation levels (all 3830 responses).

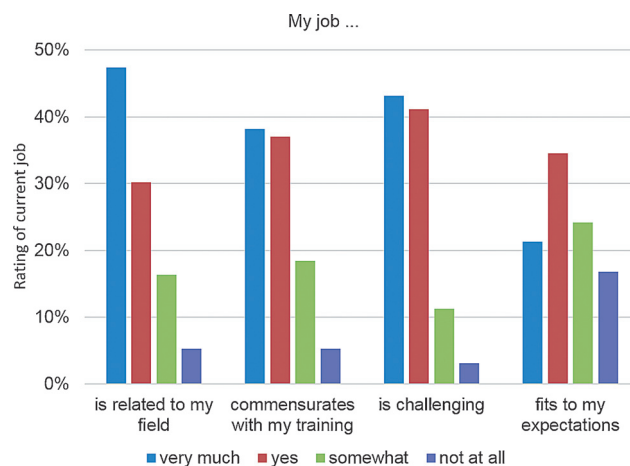
	Median age	[%] Females	[%] in native country
B.Sc. or equiv	38	41	93
M.Sc. or equiv	33	44	88
Ph.D. or equiv	40	37	80
Habilitation	51	29	89

Table 3. Graduates of 2013: Median age, share of women and native workers for the four major graduation levels.

	No. of Responses	Median age	[%] Women	[%] in native country
B.Sc. or equiv	22	24	36	86
M.Sc. or equiv	79	25	49	76
Ph.D. or equiv	56	30	52	84

**Figure 15.** Current job contracts of chemists in Europe.**Figure 16.** Current employment status of chemists in Europe.

chemists in Romanian higher education is higher than in any other European country. The same is true for the manufacturing industry in Spain (42%). Manufacturing industry is by far the most dominating employer sector for chemists in Spain, but this does not mean that the Spanish chemical industry is three times larger than the British chemical industry (14% of jobs for chemists in UK). What Figure 19 clearly shows is the share of a particular employer sector for the job market for chemists in a particular country. Moreover, it depicts the varying requirements of the job market in different European countries.

**Figure 17.** Current job and satisfaction (all responders).

Industry was identified as the most important employer for chemists in Europe (Figure 18). The whole industry range can be subdivided into 25 industrial sectors. These sectors are of quite different importance for the job market for chemists (Figure 20). Of the 2445 chemistry graduates of the last 15 years, 1058 submitted data about their job in industry. The sector Chemicals is absolutely dominating, followed by the Healthcare industry. No jobs were reported by chemists for the sectors Radio and Telecommunications Terminal Equipment (R&TTE), Space, and Toys.

Sufficient data for further evaluation are available for seven countries and twelve industrial sectors (Figure 21). These twelve industrial sectors provide 95% of jobs for chemists, both with respect to all responders and to the seven evaluated countries. Common for all countries is the dominance of the Chemicals sector. The importance of the Healthcare industry is distinctly reduced in the Southern countries. The role of the remaining ten industrial sectors is quite diverse and looks rather like a fingerprint for a particular country.

Large companies employ by far most of the responders from industry (73%, Table 4). Chemists employed by small or medium enterprises (SME) submitted 27.5% of the responses. Associations and platforms provide only a small number of jobs (3%).

Which chemical discipline dominates the current job? Responders of all employer sectors, not only from industry, were asked this question. The common division into chemical sub-disciplines is different for educational issues (Figure 5) and for job requirements (Table 5). This is caused by the much greater diversity in the industrial superstructure than the educational foundation. Job disciplines like environmental chemistry, which currently offers 6% of all jobs for chemists, require a composition of various educational disciplines, hence this kind of job disciplines cannot simply be added to one of the educational disciplines. On the other hand, five of the six job disciplines, which each provide 5% or more of the current jobs for chemists, are also found in Figure 5 as educational disciplines. Two of them, analytical chemistry and materials chemistry, have higher shares in the job market than in the educational system. Chemical engineering, organic chemistry and general

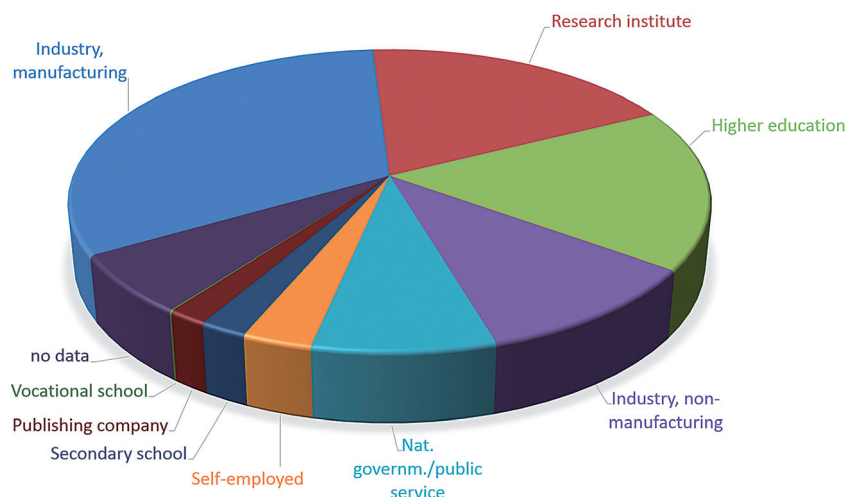


Figure 18. Where the jobs are: employer sectors for chemists in Europe (all responders).

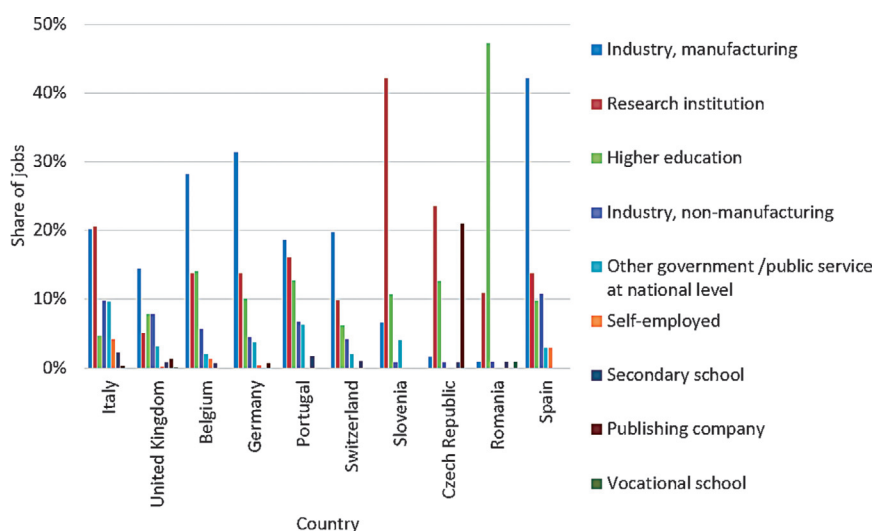


Figure 19. Varying importance of employer sectors for the job market of chemists in the countries with sufficient data (graduates of the last 15 years, 10 most responding countries).

chemistry are less frequently selected as dominating the current job.

Almost every second responder selected research and development as their current job function (43%, Table 6). Education follows far behind (12%). The main field is led by production (7%) and analytical services (6%). The top seven functions currently account for 95% of all specified jobs.

A possible influence of the discipline of the highest graduation on the current job function was evaluated for the graduates of the last 15 years. For statistical reasons only the top seven job functions are depicted in Figure 22. The outstanding role of research and development for chemists—in particular young chemists—in Europe is very evident. The role of the graduation disciplines for the job function research and development corresponds quite well with the results for the academic education shown in Figure 5. Graduates of all chemical disciplines have more or less comparable chances of finding a job in research and development. Nevertheless, some pecu-

liarities become evident: graduates of analytical chemistry are clearly preferred in analytical services, in health/safety/environment, and in quality control. Graduates of chemical engineering experience better chances in production, in health/safety/environment, and in project management; graduates of chemical education dominate the education sector.

Of interest was the question, to which extent the current job function may depend upon the graduation year. The same set of responses was evaluated as that in Figure 22. The top seven job functions now account for 90% of all submitted job functions. The expected dominance of research and development is found again (Figure 23). Depicted in Figure 23 is the absolute number of responses, accordingly, Figure 23 should be related to the age distribution of all responders (Figure 1). Apart from a certain offset, the results for research and development resemble the age distribution quite well. In contrast, all other job functions exhibit their maxima at earlier graduation years (increasing experience in the job). This points to a career path from research and development to other job functions upon increased experience in the field.

There is an ongoing dispute about unemployment on one side and an alleged lack of candidates for vacant jobs. Here the following approach was used to tackle this question: of the graduates of the past 15 years, 705 indicated they have a management position, 1740 do not have a management position. Of the 705 managers, 375 recruit new staff. Of the 1740 non-managers, 126 recruit new staff. Of the managers, 178 reported problems in finding employees. Of the non-managers, 57 reported the same kind of problems. Based on the responses of the managers we evaluated the situation for countries with sufficient data (Figure 24). For some countries the number of recruiting managers, who report problems to find people is at the same level as the number of recruiting managers who do not experience problems (Italy, Belgium, Switzerland), whereas in other countries a clear majority of managers do not report problems of finding people (UK, Germany, Portugal).

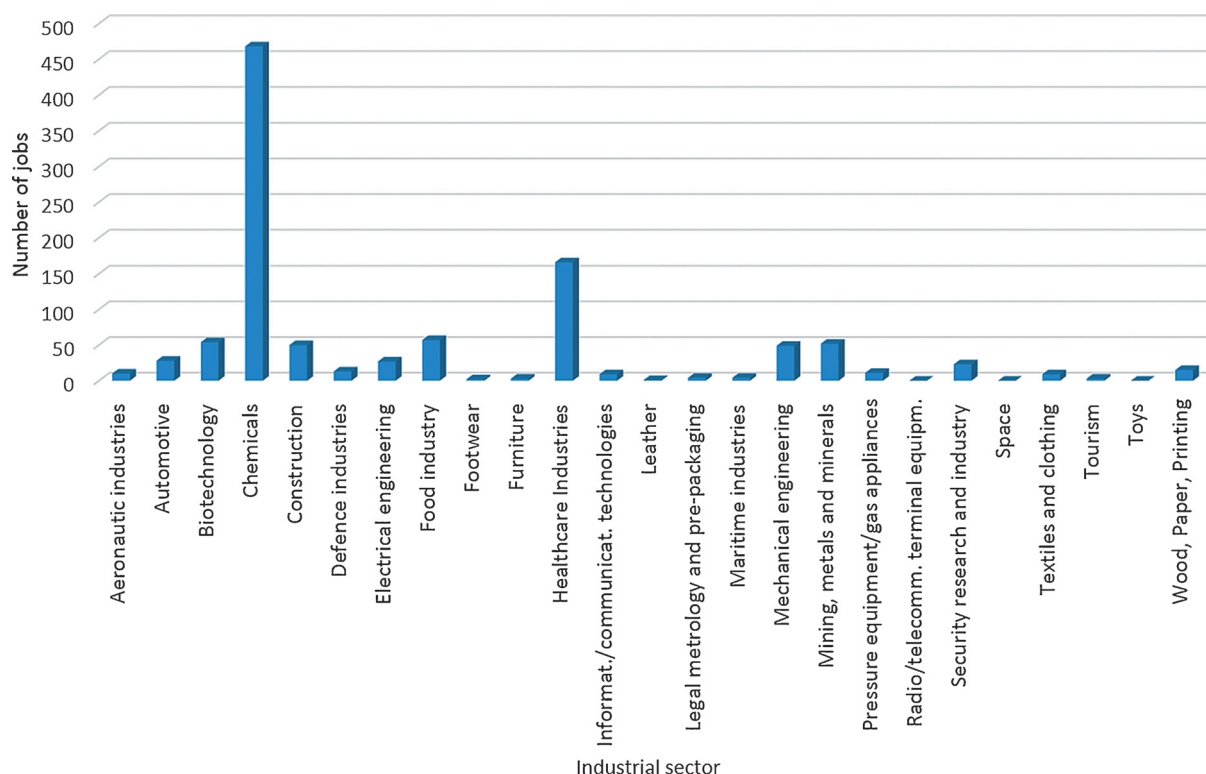


Figure 20. Varying importance of industrial sectors for the job market of chemists in the evaluated countries (graduates of last 15 years working in industry).

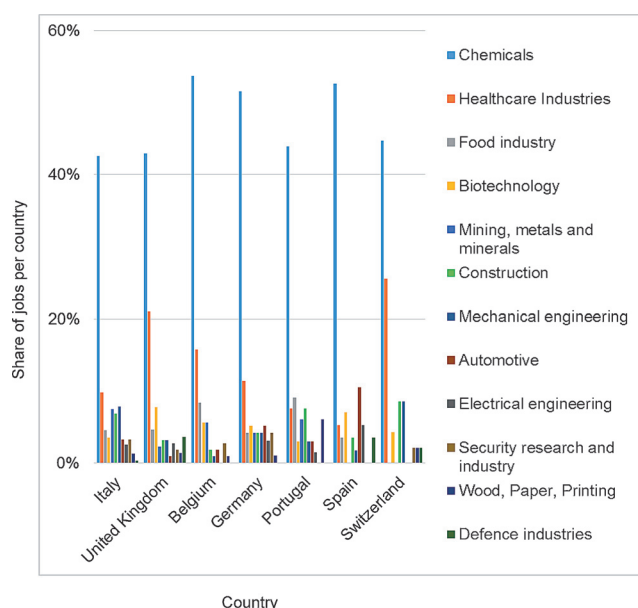


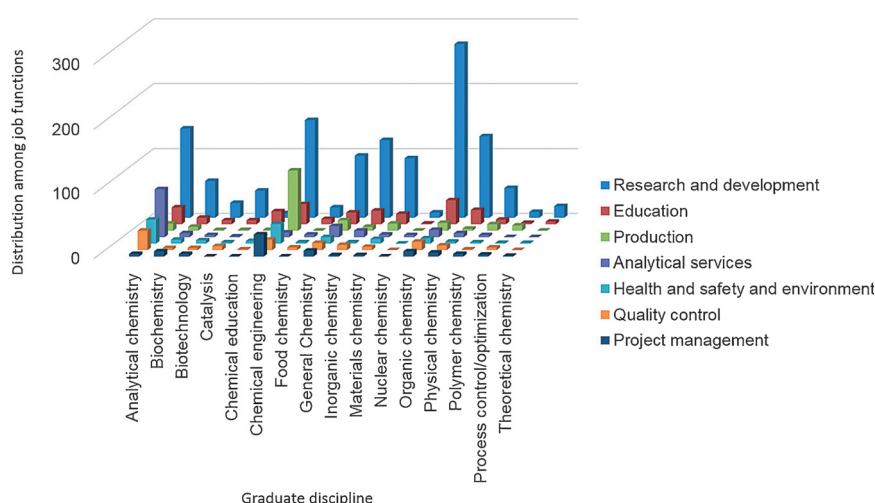
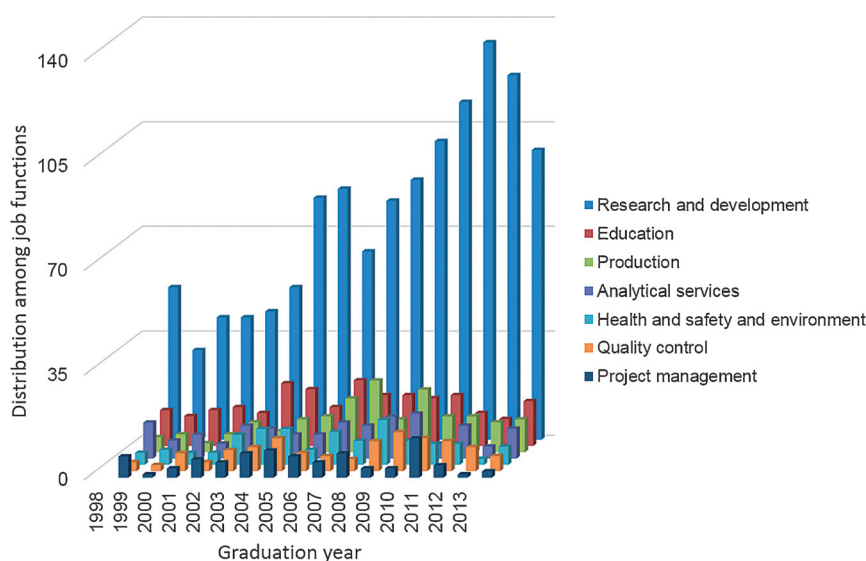
Figure 21. Varying importance of industrial sectors in countries for which sufficient data are available (every country normalized to 100%, countries and sectors with insufficient data not shown).

Table 4. Employment by industrial size (values rounded).						
	Post second. [%]	Short-cycle [%]	B.Sc. [%]	M.Sc. [%]	Ph.D. [%]	Habil. [%]
Large industry	1	2	16	28	25	1
SME		0.5	5	12	9	1
Association/platform				1	1	1

Table 5. Chemical disciplines dominating the current job.			
Discipline	[%]	Discipline	[%]
Analytical chemistry	17	Organometallic chemistry	1
Chemical engineering	9	Green chemistry	1
Organic chemistry	9	Construction materials	0.8
Materials chemistry	7	Chemo-informatics	0.8
Environmental chemistry	6	Pharmacology	1
General chemistry	5	Photochemistry	1
Polymer chemistry	4	Molecular biology	1
Pharmaceutical chemistry	4	Chemical biology	0.6
Physical chemistry	4	Supramolecular chemistry	1
Inorganic chemistry	3	Natural products chemistry	0.4
Biochemistry	3	Atmospheric chemistry	0.4
Chemical education	3	Agrochemistry	0.3
Medicinal chemistry	3	Astrochemistry	0.1
Food chemistry	3	Flavor chemistry	0.1
Formulation chemistry	3	Oenology	0.1
Petrochemistry	2	History of chemistry	0.1
Electrochemistry	2	Marine chemistry	0.1
Nanotechnology	1	Phytochemistry	0.1
Surface chemistry	1	Geochemistry	0.0
Nuclear chemistry	1	Histochemistry	0.0
Theoretical chemistry	1	no data	0.1

Table 6. Current job functions of all responders.

Job function	[%]
Research and development	43
Education	12
Production	7
Analytical services	6
Health/safety/environment	5
Quality control	5
Consulting	4
Project management	4
Customer relations	2
Administration	2
Regulatory affairs	2
Information management	1
Supply chain management	1
Intellectual property rights	1
Risk assessment	1

**Figure 22.** Relation between chemical disciplines, in which the highest graduation was obtained, and the current job function (graduates of the last 15 years).**Figure 23.** Influence of the graduation year on the actual job function of the responders (graduates of the last 15 years).

6. Continuing Education: Participation, Topics, Skills

Participation in continuing education decreases statistically with increasing qualification level. The data in Table 7 refer to the percentage of people who participated in one or more events. Some responders attended several courses. For the most responding countries we evaluated the data of the graduates of the last 15 years in more detail (Figure 25). Of the 2445 graduates in this group, 601 attended at least one event. The maximum is 33 attended courses by one of the graduates of the last 15 years.

The anonymized responses of the graduates of the last 15 years were sorted according to their working country and in order of diminishing participation in continuing education. For this reason, the range of each evaluated country starts with

a maximum, at the left and extends towards the right until the next maximum indicates a new country. The general picture is almost the same for all evaluated countries: The majority of responders did not report any event of continuing education (length of the line at the abscissa level zero). The only exception is Romania, where only a minority did not report any event. The peaks for the attendees show a distinct broadening in their lower half. This means for those who participated that the majority attended a single digit number of events of continuing education, but a smaller group of busy attendees raises the peak heights to the range of 20–30 events (exceptions: maximum for Italy above 30, maximum for Czech Republic below 20). The survey results do not provide information on why such high numbers of educational events needed to be attended within only 15 years.

Next we analyzed the participation of employees with respect to their current employer sector. Of all 2445 graduates of the last 15 years, 557 chemists participated in continuing education (23%). Within the ten most responding countries, the percentage of participants is only slightly higher (24.5%). Figure 26 depicts for the employer sectors the percentage of



Figure 24. Manager's views on the question of finding new employees in different countries.

Table 7. Participation in continuing education (all participants).	
	Participants [%]
B.Sc. or equiv	33
M.Sc. o equiv	27
Ph.D. or equiv	24
Habilitation	20

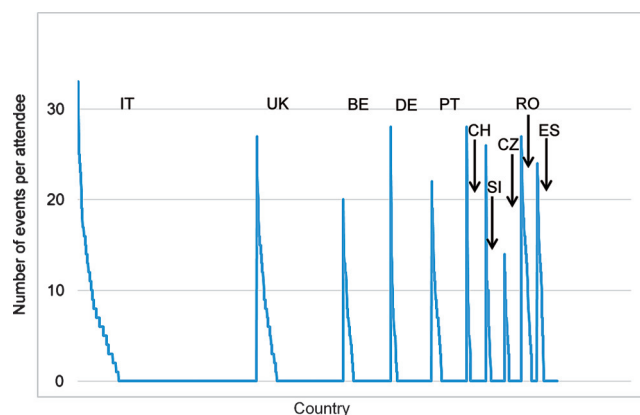


Figure 25. Participation in continuing education (10 most responding countries, graduates of the last 15 years).

responders who participated in continuing education. The distinctly larger values for secondary schools and for self-employed should be interpreted cautiously as the number of responses from these employer sectors are relatively small (cf. Figure 18). In contrast, the number of responses from the research sector is large; hence, the corresponding result is quite reliable. This result points to a distinctly lower participation of employees from the research sector in events of continuing education, lower than in any other employment sector.

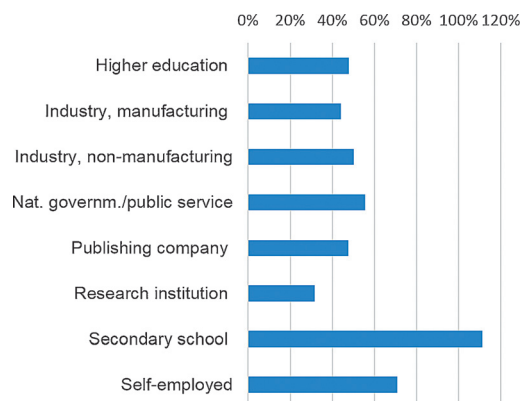


Figure 26. Participation in continuing education versus employer sector (graduates of the last 15 years, 10 most responding countries, normalized per sector, multiple participation included, insufficient data for vocational schools).

With respect to the content of the attended events, we separated topics (e.g., chemistry, physics, biology) and skills (e.g., management skills, social skills). The graduates of the last 15 years reported 1035 participations focusing on topics and 4366 participations focusing on skills. First, we investigated participation in events focusing on topics (Table 8). In total, chemistry was by far the most chosen topic by all graduation levels, followed by business and management. This large interest in business and management suggests an apparent deficit during the education of chemists of all qualification levels in more or less all employer sectors. Informatics ranks second in the science area. Material science is the preferred topic in the area engineering/technology, and environmental chemistry among life sciences.

From which employment sectors did the participants of Table 8 come? Figure 27 clearly reveals the dominating role of continuing education in chemistry for all employment sectors. With respect to particular employment sectors, most participants in continuing education come from industry. Conspicuous is in addition the outstanding interest in chemistry topics by employees of the sectors higher education and research institution, as well as the dominating participation of industry employees in business and management education.

Next we investigated the participation in events of continuing education focusing on skills. Table 9 lists the wide range of educational targets on offer. They can be combined into groups such as management skills and social skills. For self-management skills not a single participation was reported.

Like in the case of continuing education focusing on topics, also in continuing education focusing on skills most participants come from industry (Figure 28). Compared to the size of the employment sector (cf. Figure 18), higher education is distinctly more interested in this kind of continuing education than research institutions.

7. Salaries

Salaries of chemists with a Master's degree as highest qualification, working in Italy full time and having a permanent con-

Table 8. Participation in continuing education by topic (absolute number of attended events, graduates of the last 15 years, insufficient data for post-secondary and short-cycle degrees).

	Chemistry	Physics	Biology	Mathematics	Informatics
B.Sc. or equiv	34	8	6	5	6
M.Sc. or equiv	103	16	13	11	20
Ph.D. or equiv	109	18	14	7	21
Habil.	10	0	3	0	1
	Biotech- nology	Nanotech- nology	Material science	Electrical engineering	Mechanical engineering
B.Sc. or equiv	1	8	7	2	3
M.Sc. or equiv	10	13	30	6	10
Ph.D. or equiv	14	13	27	2	4
Habil.	2	2	4	0	0
	Environm. chemistry	Life science	Medicine	Education	Business, management
B.Sc. or equiv	14	3	2	5	13
M.Sc. or equiv	42	9	14	29	73
Ph.D. or equiv	40	13	11	31	58
Habil.	2	2	1	6	0
	Law	Arts	Humanities	Social sciences	
B.Sc. or equiv	3	0	2	3	
M.Sc. or equiv	21	3	7	12	
Ph.D. or equiv	16	4	11	11	
Habil.	1	0	1	3	

tract are depicted in Figure 29. This group is shown as it is the largest available subset of a well-defined group. This data are arranged in order of a) years after receiving the Master's certificate (i.e. years of experience) and b) increasing salary. The minima indicate single digit salaries for one year full-time work under a permanent contract. Such values are not credible, but

they structure the diagram nicely. Some of the maxima are doubtful as well. The red line in Figure 29 connects the average values in a semi-quantitative manner. This line reveals starting salaries and wage increases upon growing experience of the employee. There are insufficient data beyond 20 years of experience, hence the red line was not extended beyond this time.

The same kind of evaluation was performed with datasets of other countries, for which sufficient responses were obtained. Figure 30 provides a semi-quantitative comparison of starting salaries and wage increases of chemists holding a Master's degree, working full time under a permanent contract. This graph does not take into account different costs of living, taxation etc. Included in Figure 30 is a comparison with results of the ACS survey collected in 2009.^[14] The values stand for all chemists and are given in US\$. The exchange rate on December 01, 2009 was 1 US\$ = 0.67 €. For comparison, the ACS survey of 2013 provided salaries for industrial chemists.^[15] The experience is reported in years since the Bachelor's degree was obtained. Wages for male industrial chemists rise from 66.6 TUS\$ (TUS\$ = thousand US\$: 2–4 years after B.Sc.) to 101.2 TUS\$ (20–24 years after B.Sc.).

The evaluation of higher statistical reliability was based on the calculation of median values in order to omit the extreme values. Master's and Ph.D. degree holders working full time and a permanent contract and three years or more experience were included. The calculation was performed for countries with a sufficient number of responses (Table 10). The large spread of median salaries is evident. At Ph.D. level a factor of

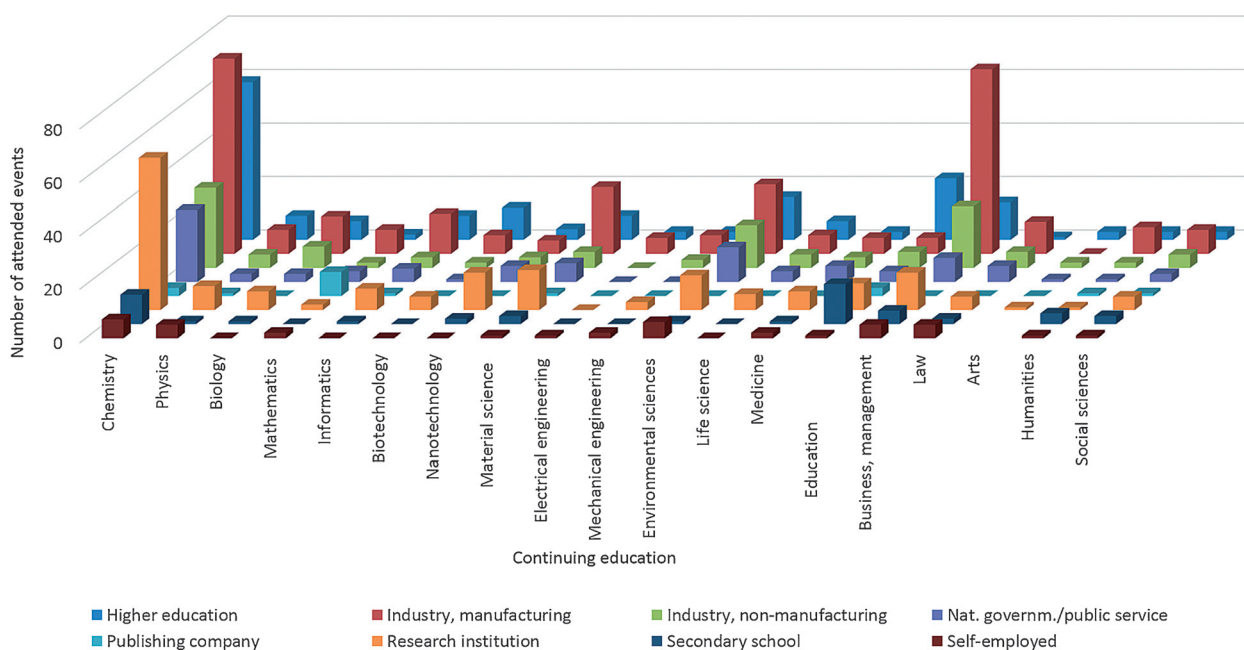


Figure 27. Absolute participation in continuing education with focusing on topics versus employment sector (graduates of the last 15 years, multiple participation included, insufficient data for vocational schools).

Table 9. Participation in continuing education by skills (absolute number of attended events, graduates of the last 15 years, insufficient data for post-secondary and short-cycle degrees).

	Industry, manufacturing	Higher education	Industry, non-manufacturing	Research institution	National government/public service	Secondary school	Self-employed	Publishing company
Management skills								
strategic	53	16	21	14	8	5	3	2
coaching	51	28	16	17	12	4	2	2
change	48	6	17	6	9	5	2	0
project	92	40	33	25	18	6	6	1
process	53	13	12	14	7	1	3	0
quality	49	16	15	12	15	4	5	1
people	26	14	8	13	8	3	1	0
Social skills								
team	94	60	34	55	29	16	10	4
social	56	38	23	23	13	12	6	1
communication	82	55	35	46	20	16	8	3
networking	53	21	22	22	16	8	7	1
intercultural	40	23	13	16	8	12	4	1
Problem-solving skills								
analytical	93	45	28	43	27	8	8	5
interdisciplinary	63	50	26	39	21	10	7	1
initiative	58	23	22	23	12	7	7	1
multi-skilling	40	22	20	24	13	7	4	1
creativity	46	30	18	23	16	8	7	1
Hard skills								
legislative	46	18	19	15	26	4	6	2
regulatory	86	33	39	31	40	9	12	1
language	61	45	18	27	14	7	6	4
e-skills	39	45	14	18	16	7	3	0
Marketing skills								
technical	65	27	25	30	16	2	6	2
product	54	9	11	15	8	4	4	0
development	43	11	13	21	6	1	3	0
Entrepreneurial skills								
supplier	36	13	17	11	9	1	4	1
business	46	12	19	14	6	1	3	0
trend	23	3	8	9	6	3	5	0
Self management skills	0	0	0	0	0	0	0	0

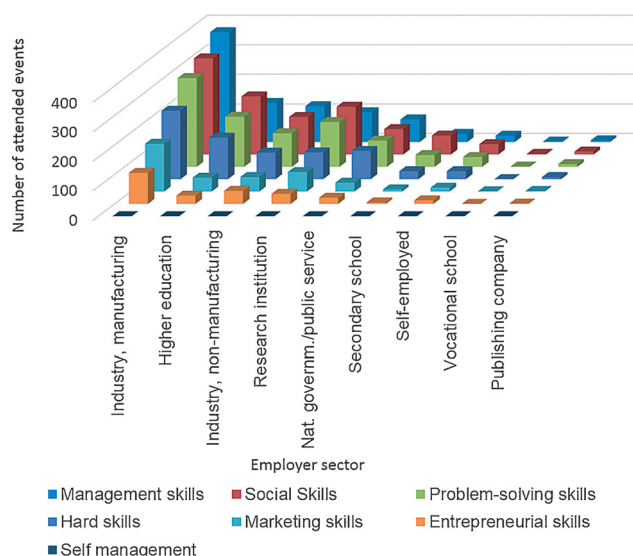


Figure 28. Absolute participation in continuing education with focus on skills versus employment sector (graduates of the last 15 years, multiple participation included, insufficient data for vocational schools).

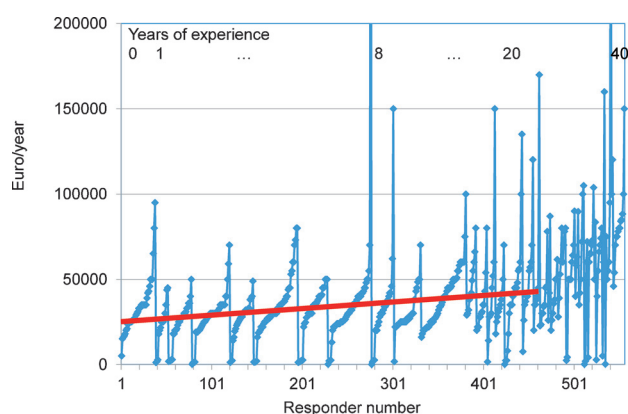


Figure 29. Salaries: M.Sc. Italy: Fully employed, permanent contract.

26 is observed. For comparison: the ACS survey^[16] reports median values for wages in different regions of the USA. The observed wages for male M.Sc. holders range from 65.0 TUS\$ (in West, South, Central) to 90.0 TUS\$ (Pacific Coast). The factor between both values is 1.4. For male Ph.D. holders the lowest wages are paid in West, North, Central (83.3 TUS\$), the highest in the Pacific Coast area (106.3 TUS\$). This gives a factor of 1.3

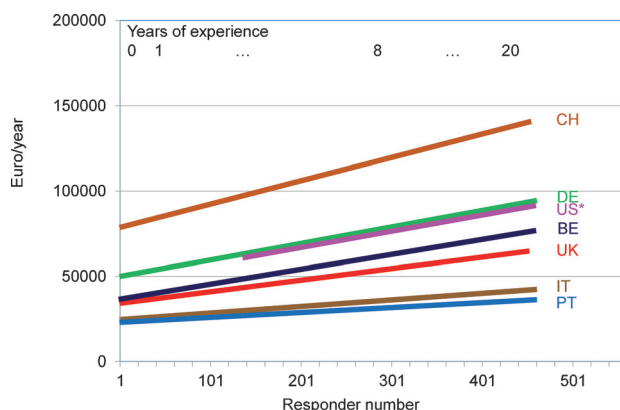


Figure 30. Salaries: M.Sc. Comparison: Fully employed, permanent contract.

Table 10. Median salaries (EUR): Full time, permanent contract, > 3 years experience (i.d.: insufficient data).

Country	Master		Ph. D	
	No. of responders	Salary [€]	No. of responders	Salary [€]
Italy	242	35 000	88	38 000
UK	122	49 302	311	59 764
Belgium	62	53 150	67	83 000
Germany	15	51 000	103	80 000
Portugal	49	35 000	30	36 000
Switzerland	13	98 000	90	130 000
Czech Republic	i.d.		18	14 966
Romania	i.d.		48	5000
Spain	27	43 000	i.d.	

between lowest and highest median wages. For comparison the SPIE (International Society for Optics and Photonics) survey^[17] showed: industry, men, years employed: < 5: 46168 US\$; 16–20: 91515 US\$.

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Keywords: chemist employment survey · chemists · European chemistry · European chemists

- [1] *Chem. Eng. News*, **2013**, 91 (September 23), 9–14.
- [2] *Künftige Ausbildungserfordernisse für ChemikerInnen in Österreich* (Future requirements for education of chemists in Austria), Austrian Chemical Society 1999, private communication.
- [3] <http://www.rsc.org/learn-chemistry/resources/business-skills-and-commercial-awareness-for-chemists/docs/skillsdoc1.pdf>.
- [4] http://www.eps.org/?page=policy_economy.
- [5] http://spie.org/Documents/CareerCenter/2014-Global-Salary-Report.pdf?WT.mc_id=JSALARYSURVEY2014B.
- [6] R. Salzer, P. Taylor, N. Majcen, E. Varella, I. Kozaris, *Anal Bioanal Chem.* **2015**, 407, 639–643.
- [7] *Chem. Eng. News*, **2013**, 91 (September 23), 10.
- [8] *Chem. Eng. News*, **2009**, 87 (March 09), 37.
- [9] *Chem. Eng. News*, **2013**, 91 (September 23), 14.
- [10] *Chem. Eng. News*, **2014**, 92 (June 2), 28.
- [11] *Chem. Eng. News*, **2013**, 91 (September 23), 13.
- [12] *Chem. Eng. News*, **2011**, 89 (March 14), 49–53.
- [13] *Chem. Eng. News*, **2013**, 91 (September 23), 11.
- [14] *Chem. Eng. News*, **2010**, 88 (July 12), 40.
- [15] *Chem. Eng. News*, **2013**, 91 (September 23), 11–12.
- [16] *Chem. Eng. News*, **2010**, 88 (July 12), 38.
- [17] <http://www.photonics.com/Article.aspx?PID=5&VID=116&IID=770&AID=56538>.
- [18] www.ectn-assoc.org (accessed 22.07.2014).
- [19] <https://ec.europa.eu/jrc/institutes/irrm/>, accessed 22.07.2014.
- [20] <http://www.euchems.eu/>, accessed 22.07.2014.
- [21] <http://www.cefic.org>, accessed 22.07.2014.
- [22] <http://www.ec2e2n.net>, accessed 22.07.2014.
- [23] <https://www.gdch.de>, accessed 22.02.2015.
- [24] <http://www.merckgroup.com/en/index.html>, accessed 22.02.2015.

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