THE CONDITIONS OF SCIENTIFIC RESEARCH IN CHEMISTRY: A VIEW FROM THE BRAZILIAN COMMUNITY

Maria Aparecida H. CAGNIN

Conselho Nacional de Desenvolvimento Científico e Tecnológico
Assessoria de Planejamento/Coordenação de Estudos
Av. W3 Norte - Q. 507 - Bl. B - Ed. CNPq
70.740 - Brasília - DF - Brasil

Sociedade Brasileira de Química
Instituto de Química/Universidade de São Paulo
Cidade Universitária - Caixa Postal 22296
01498 - São Paulo - SP - Brasil

ABSTRACT

The aim of this paper is to analyse the environment in which scientific research in Chemistry is carried out in Brazil. This task is accomplished by the analysis of a questionnaire which was distributed among academic scientists by the Brazilian Chemistry Society. This survey examined the attitudes of scientists towards their activities at the different institutions, at the national level, and by region, and also according to their research fields within Chemistry. The researchers' evaluation of the positive and negative factors facing the scientific development of Chemistry were examined in the light of peer review trials which focus on the distribution of fellowships and grants, and on the assessment of post-graduate programmes in Chemistry. By examining the linkages that emerged from the researchers' views and expert judgements of research and post-graduate activities, as well as the input-output indicators connected with them, it was possible to draw up strategies and recommendations to be considered by the government, national enterprises, and the academic community itself, with regard to the improvement of an endogenous progress in Chemistry. Presently, this is of keen importance due to the relationship between chemical knowledge and intensive knowledge technologies such as fine chemicals, biotechnology, new materials, among others.

RESUME

L'objectif de cet article est d'analyser le contexte dans lequel se déroule la recherche scientifique en chimie au Brésil. Ceci est fait en examinant les réponses à un questionnaire qui a été distribué parmi les chercheurs essentiellement universitaires par la Société Brésilienne de Chimie. Ce questionnaire examine les attitudes des chercheurs face à leurs conditions de travail au sein des institutions de recherche au niveau national et régional ainsi que par disciplines. L'évaluation par les chercheurs des facteurs négatifs

et positifs du développement scientifique sont examinés et sont mis en relation avec les processus de jugements par les pairs qui permettent d'établir les distributions de bourses de recherche et d'effectuer l'évaluation des programmes d'enseignement et de recherche de "post-graduation". En examinant conjointement les opinions des chercheurs et les jugements des experts sur la recherche et les programmes de "post-graduation", ainsi que les indicateurs d'input et output qui leur sont liés, il a été possible d'effectuer une série de recommandations au gouvernement, aux entreprises nationales et à la communauté scientifique elle-même pour l'amélioration et le progrès endogène de la recherche en Chimie. Ceci est aujourd'hui très important notamment dans le cas du développement de technologies nouvelles, comme le sont par exemple la chimie fine, les biotechnologies, les nouveaux matériaux.

INTRODUCTION

The present study is related to a future programme to be established by the brazilian governement jointly with the Brazilian Chemistry Society (SBQ)-which assembles the majority of researchers and post-graduate students working in universities and isolated institutes-, the"Chemistry Programme for the Next Decade". The study focuses only on the academic research environment with the purpose of evaluating its fragility as well as its potentialities, through the use of scientific indicators.

METHODOLOGY

Three basic topics on the research environement are analysed in this survey. This first topic consists of 19 items, listed in Table 1, and organized under three categories: Intellectual Capital, Infrastructure, and Investments. Answers were evaluations based on grades ranging from 1 to 5.

Topics 2 and 3, respectively, present the opinion of researchers on the three most serious problems and the three main factors which contribute to the efficiency of the research and post-graduate activities (RPG), all ranged from the most important to the least relevant. The analysis of these three factors, when confronted with the results of the first topic, allow us to match the information and to grasp, in a more consistent manner, the circumstances under which academic research in Chemistry is carried out in Brazil. This is done by putting together the "problems" and "factors" under the same categories as in the first topic, and by using a point scale (3 points for a factor considered of greater importance; 2 points for the second most important; and 1 point for the third most important factor) it was possible to classify the related factors in each answer. The point values attributed to different opinions and attitudes reflected in the study were correlated by region and by university.

Table 1 Classification of the first items of the first topic by category

CATEGORY	ITEM	CONTENTS
Intellectual Capital	01	Research quality performed in your State in chemistry
	02	Research quality performed in your field
	03	Quality of post graduate students in the universities of your State in your field
	04	Quality of post graduate students in the universities of your State in chemistry
	05	Number of researchers in your State in your field
Infrastructure	06	Infrastructure in your Department for research and post graduate activities (RPG)
	07	Infrastructure in your State for RPG in chemistry
	08	Infrastructure in your State for RPG in your field
	09	Accessible equipment for RPG
	10	Equipment in your State for RPG in chemistry
	11	Equipment in your State for RPG in your field
	12	Availability of solvents, reagents, and other imported items of consumption
	13	Availability and quality of the services for the maintenance of equipments
Investments	14	Availability of resources for research in your laboratory
	15	Availability of resources for research in chemistry in your State
	16	Availability of resources for research in your field
	17	Suitability of grants and scholarships offered by CNPq to the needs of RPG in chemistry in your State in relation to their monetary values
	18	Suitability of grants and scholarships offered by CNPq to the needs of RPG in chemistry in your State in relation to their types
	19	Suitability of FINEP's grants to the needs of RPG in your state

The sample (Table 2) consisted of 168 responses and enabled us to trace a profile which reflects a cross section of the opinions of the researchers. 115 (or 68.4%) of the respondents held Doctorate degrees, and thus were best placed to judge the conditions of academic research; 32 (or 19%) were Masters degree holders; and 17 (or 10.2 %) were post-graduate students, or graduates. In this manner the points of view of all the main participants in the social aspects of the scientific process were taken into account, but the predominance of Doctorate degree holders in the sample ensures that the weight of their opinions prevails[1] .

[1] It is significant that the 115 Doctors in the sample account for more than half (or 51.3%) of the 224 currently receiving research fellowships in Chemistry from CNPq (the National Council for Scientific and Technological Development) at the time of this study , and that

Table 2A- Number of answers to the questionnaire by chemistry field, geo-economic region and the researcher's level

CHEMISTRY FIELD	NORTH						NORTHEAST						CENTRAL WEST					
	D	M	G	U	W I	TT	D	M	G	U	W I	TT	D	M	G	U	WI	TT
ORGANIC	2	3	5	1	1	12	3	2	-	-	-	5	4	2	-	1	1	8
PHYSICAL	-	-	-	-	-	-	5	1	-	1	-	7	1	-	-	-	-	1
ORGANIC	-	-	-	-	-	-	9	2	-	-	1	12	1	-	-	-	-	1
ANALYTICAL	-	-	-	-	-	-	3	-	-	-	-	3	-	-	-	-	-	-
EDUCATION	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-
BIOCHEM.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	2	3	5	1	1	12	20	6	-	1	1	28	6	2	-	1	1	10

Table 2B- Number of answers to the questionnaire by chemistry field, geo-economic region and the researcher's level.

CHEMISTRY FIELD	SOUTHEAST						SOUTH						BRAZIL	
	D	M	G	U	WI	TT	D	M	G	U	WI	TT	TT	%
ORGANIC	26	2	-	-	1	29	7	4	-	1	-	12	66	39.3
PHYSICAL	25	2	-	1 *	-	28	3	3	1	-	-	7	43	25.6
INORGANIC	3	1	1	-	-	5	5	2	-	-	-	7	25	14.9
ANALYTICAL	10	2	-	-	-	12	4	3	-	2	-	9	24	14.3
EDUCATION	-	1	1	1 *	-	3	-	1	-	1*	-	2	6	3.6
BIOCHEM.	3	-	-	-	-	3	1	-	-	-	-	1	4	2.4
TOTAL	67	8	2	2	1	80	20	13	1	4	-	38	168	100.0

*with specialization course
D= Doctoral Scientist; M= Master; G= Post Graduate Student; U= Graduate; WI= Without Information.

It should also be stressed that the sample gives us a representative national cross section, as the regional distribution of responses from doctor-researchers is compatible with the geographical distribution of Chemistry researchers around

---

they also represent more than a quarter (or 27%) of the total Doctors/faculty-members engaged in post-graduate programmes in Chemistry in the whole country according to CAPES (Coordinating Agency for Advanced Training of High Level Personnel).

the country[2].The sample also remains valid when it is seen from the point of view of the traditional fields of Chemistry[3].

RESULTS

Table 3. Regional distribution of the answers for the first topic by category

		NORTH		CENTRAL -WEST		NORTH-EAST		SOUTH-EAST		SOUTH		BRAZIL	
CATEGORY	DEGREE	#	%	#	%	#	%	#	%	#	%	#	%
Intellectual Capital	very bad	0	0.0	0	0.0	1	3.6	0	0.0	0	0.0	1	0.6
	bad	1	8.3	2	20.0	4	14.3	4	5.0	7	18.4	18	10.7
	fair	10	83.3	7	70.0	10	35.7	33	41.3	23	60.5	83	49.4
	good	1	8.3	1	10.0	12	42.9	38	45.7	6	15.8	58	34.5
	very good	0	0.0	0	0.0	1	3.6	5	6.3	2	5.3	8	4.8
Infra structure	very bad	0	0.0	0	0.0	1	3.6	0	0.0	3	7.9	4	2.4
	bad	2	16.7	3	30.0	17	60.7	24	30.0	18	47.4	64	38.1
	fair	10	83.3	4	40.0	6	21.4	32	40.0	12	31.6	64	38.1
	good	0	0.0	3	30.0	4	14.3	24	30.0	5	13.2	36	21.4
	very good	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Investments	very bad	1	8.3	0	0.0	4	14.3	1	1.3	3	7.9	9	5.4
	bad	1	8.3	6	60.0	13	46.4	7	8.8	8	21.1	35	20.8
	fair	9	75.0	4	40.0	10	35.7	53	66.3	20	52.6	96	57.1
	good	1	8.3	0	0.0	0	0.0	18	22.5	5	13.2	24	14.3
	very good	0	0.0	0	0.0	1	3.6	1	1.3	1	2.6	3	1.8
# of individuals		12	100	10	100	28	100	80	100	38	100	168	100

[2] If the regional distribution of research fellowships in Chemistry by CNPq is taken as basis. The relative importance of the five geo-economic regions of the country, in terms of their contribution to Chemistry, is also adequately reflected in the number of institutions and research centres surveyed: 3 in the North, 2 in the Central-West, 8 in the Northeast, 13 in the South, and 17 in the Southeast.

[3] By comparison between Doctors' research field who responded to the survey with the list of those receiving research fellowships from CNPq at the time when the survey was being carried out (1987).

Table 3 shows that in the general view of the Chemistry researchers, research activities in Brazil could, on average, count on Intellectual Capital which they rated as Fair to Good, and an Infrastructure that they rated as being Bad to Fair, and investments that they rated as being Fair.

Intellectual Capital

Although the grade Fair is the most common feature of the survey, higher values are attributed to this category -especially by groups working in the Southeast, the Northeast, and to a lesser extent, in the Central-West.

Table 4A and 4B show that the groups which awarded the highest ratings to their activities were those engaged in research in the fields of Physical Chemistry (in São Paulo, Pernambuco, and Santa Catarina); Organic Chemistry (in São Paulo, Rio de Janeiro, Ceará, and Santa Catarina); and Analytical Chemistry (in Rio de Janeiro).

Table 4A. Distribution of the regional and national answers of the first topic by category and chemistry field (inorganic and analytical chemistry) .

		Inorganic Chemistry						Analytical Chemistry			
CATEGORY	DEGREE	NO	CW	NE	SE	SU	BR	NO	SE	SU	BR
Intellectual Capital	very bad	0	0	1	0	0	1	0	0	0	1
	bad	0	0	1	0	0	1	0	0	1	1
	fair	0	1	6	1	6	14	2	5	7	14
	good	0	0	4	4	0	8	1	7	1	9
	very good	0	0	0	0	1	1	0	0	0	0
Infra structure	very bad	0	0	0	0	0	0	0	0	1	1
	bad	0	0	8	0	6	14	2	2	0	4
	fair	0	1	3	3	1	8	0	8	5	13
	good	0	0	1	2	0	3	1	2	3	6
	very good	0	0	0	0	0	0	0	0	0	0
Investments	v.bad	0	0	2	0	1	3	1	0	0	1
	bad	0	1	6	0	1	8	1	1	2	4
	fair	0	0	3	4	4	11	1	9	6	16
	good	0	0	0	1	1	2	0	2	1	3
	very good	0	0	1	0	0	1	0	0	0	0
# of individuals		0	1	12	5	7	25	3	12	9	24

Table 4B. Distribution of the regional and national answers of the first topic by category and chemistry field (organic and physical chemistry).

		Org. Chemistry						Physical Chemistry					
CATEGORY	DEGREE	NO	cw	NE	SE	SU	BR	NO	CW	NE	SE	SU	BR
Intellectual Capital	very bad	0	0	0	0	0	0	0	0	0	0	0	0
	bad	1	1	1	1	3	7	0	1	2	1	2	6
	fair	10	6	0	14	6	36	0	0	1	11	2	14
	good	1	1	4	9	3	18	0	0	3	16	2	21
	very good	0	0	0	5	0	5	0	0	1	0	1	2
Infra structure	very bad	0	0	1	0	1	2	0	0	0	0	1	1
	bad	2	3	2	12	8	27	0	0	5	6	2	13
	fair	10	2	1	12	3	28	0	1	1	7	2	11
	good	0	3	1	5	0	9	0	0	1	15	2	18
	very good	0	0	0	0	0	0	0	0	0	0	0	0
Investments	very bad	1	0	0	0	1	2	0	0	1	1	1	3
	bad	1	4	3	3	3	14	0	1	3	1	1	6
	fair	9	4	2	22	6	43	0	0	3	15	3	21
	good	1	0	0	4	2	7	0	0	0	10	1	11
	very good	0	0	0	0	0	0	0	0	0	1	1	2
# of individuals		12	8	5	29	12	66	0	1	7	28	7	43

The relative density of researchers in the Northern Region is considered to be very low (grades varying between Very Bad and Bad). Table 5 also shows that the limited number of researchers in the Northern Region is still the greatest obstacle to assessing the RPG values presented for this region[4].

[4] The Chemistry research being carried out in the North is linked directly to the region's main features: the Amazon Rain Forest- Organic Chemistry, specifically Chemistry of Natural Products. It is well known that several parts of the Brazilian Amazon are being subject to a rapid process of human and economic occupation, and that this process is destroying certain environmental niches that will undoubtedly result in the extinction of species of flora that have therapeutic potential. It is necessary to give priority to its scientific progress, with a view to promoting a social/scientific process by which knowledge intensive products required for the most advanced technologies should find their supplies from natural sources. Thus special emphasis on fine chemicals and biotechnology research could transform the Amazon region into a centre for scientific research which could even alter the model of occupation and development prevalent in the region. Therefore, the starting point will be to design a plan to attract highly experienced human capital.

Table 5. Principal barriers to efficiency in the research and post graduate activities in chemistry by region.

Category	North		C. West		Northeast		Southeast		South	
Factor	#pts	%	#pts	%	#pts	%	#pts	%	#pts	%
Intellectual Capital										
Low density of qualified researchers	14	25.0	4	6.7	5	2.9	13	2.7	6	2.7
Lack of techn. support	4	7.1	3	5.0	5	2.9	14	3.0	17	7.5
Teaching hours	-	-	5	8.3	6	3.5	23	4.8	7	3.1
Administrative tasks	-	-	-	-	7	4.1	22	4.6	19	8.4
Lack of students	-	-	11	18.3	-	-	4	0.8	-	-
Poor Research env.	3	5.4	-	-	7	4.1	7	1.5	3	1.3
lack of motivation	-	-	6	10.0	-	-	-	-	-	-
Lack of courses for specific needs	-	-	-	-	-	-	-	-	8	3.5
Infrastructure										
Imports of reagents and equipments	-	-	2	3.3	3	1.8	70	14.7	10	4.4
Maintainance of equip.	3	5.4	3	5.0	18	10.5	54	11.4	17	7.5
Availability of equip	6	10.7	6	10.0	22	12.9	45	9.5	39	17.3
Access to special. library	12	21.4	5	8.3	20	11.7	48	10.1	14	6.2
Lab. and techn. infrastruct.	1	1.8	-	-	15	8.8	30	6.3	20	9.0
Comput Resources	-	-	1	1.7	-	-	6	1.3	-	-
Physical space	-	-	2	3.3	5	3.0	2	0.4	5	2.2
Univ bureaucracy	7	12.5	1	1.7	15	8.8	34	7.2	11	4.9
Investment										
ins. univ. budget	-	-	-	-	1	0.6	15	3.2	-	-
ins. extramural budget	3	5.4	3	5.0	22	12.9	16	3.4	33	14.6
The financing research systematic	-	-	2	3.3	9	5.3	28	5.9	7	3.0
Lack of a policy for S&T	-	-	-	-	5	2.9	10	2.1	1	0.4
Others	3	5.4	6	10.0	6	3.5	34	7.1	9	4.0
TOTAL	56	100.0	60	100.0	171	100.0	475	100.0	226	100.0

Therefore, the starting point will be to design a plan to attract highly experienced human capital.

At the national level it can be seen that only a very small number of people are involved in RPG in Chemistry, and that 39.3% of those surveyed rated this as Bad and 33.3% as Very Bad. The only group that did not conform to this pattern were the Physical Chemistry researchers centered on the Federal University of Pernambuco (UFPe)[5], located at the Northeastern Region.

In the Central-West the greatest obstacle to the efficiency of RPG is not the number of researchers working at the University of Brasilia (UnB), but rather the lack of post-graduate students[6] (Table 5) and this should be changed since it is clear that the presence of students[7] is a factor that enhances scientific research (Table 6).

Table 6 shows that in all regions of the country those items listed under Intellectual Capital are considered to be the most important for the efficiency of RPG[8]. The same table also shows that the North, Northeast, Southeast, and South share a factor that promotes RPG, namely the cooperative networks that have been established for scientific activities (the collaboration/exchange programmes that have been set up, and the support activities offered to other groups of researchers were frequently cited, and integrated work group of researchers were also favourably mentioned). Only the Central-Western region, where there is less integration, appears to be the exception to the rule.

Thus it is possible, from the evaluations and observations of the Chemistry researchers, to identify those factors which were most important for carrying out research. These are: the establishment and consolidation of integrated working groups in research activities; and the nurturing of collaboration and exchange systems, which seem to be the best strategies for stimulating and increasing Intellectual Capital at the post-graduate level.

There are currently in the country 32 post-graduate programmes in chemistry at the Masters level (12 were evaluated as excellent or A rating, 9 assessed as

---

5 The group of Theoretical Physical Chemistry at UFPe attributes the best grades of the Northeastern region to the items of Intellectual Capital (Good for the research quality in Chemistry; almost Very Good in relation to its field as well as for the density of its researchers, excepting the post-graduate programme, left without any grade because it was only formalized in March 1988). This group and the Organic Chemistry group of the University of São Paulo (USP) presented the highest ratio of publication per faculty member- respectively 2.9 and 3.2 in the 1985/1986 period.

6 Even though the Chemistry department at UnB possesses one of the best libraries in the country and well-equipped laboratories, and although it considers itself the best centre for Organic Synthesis, it has the drawback of the second lowest ratio between the total number of post-graduate students, and the size of the faculty staff (1.0/2.12).

7 As one of the researchers emphazised: "-When I have them".

8 In all regions, for the own qualities of the researchers set up by themselves were appointed as the main positive factor for the efficiency of RG. By intrinsic qualities it is meant: dedication, intensive work even in adverse conditions, love for the job, disposition, persistence, patience, scientific curiosity, idealism, fighting spirit, among others.

appraised due to their recent implantation) and 11 at the Doctoral level (8 rated A, 2 rated B, and 1 rated C)[9].

These programmes are located in 22 universities and 1 research institute and are heavily concentrated on the Southeastern Region (18 Masters and 7 Doctoral), namely at the State of São Paulo (55% and 64%, respectively)[10]. In general, they are characterized by a low multiplying effect -the national average advisor/students ratio was 1.0/2.83 (413 faculties to 1171 students)[11] in 1987, and by providing very low rates of training -4.5 years to complete a Masters programme and further 6.5 years to get a Doctoral degree[12].

One proposal could be to abolish the requirement that demands that, in order to participate in a PhD programme, a candidate must first have his/her Masters degree, as this would make it possible, after a careful selection process, to choose the most brilliant of the graduates and engage them directly in Doctoral programmes. This is the usual procedure in Chemistry in other countries, where the Masters degree is seen as a final stage in studies, rather than as an intermediate step before the Doctorate[13]. Such measure would help to increase, in medium run. Another piece of information that reinforces this recommendation and confirms the researchers' evaluation is that the number of Doctors/faculty-members in Chemistry only started to increase after the second half of the 1980's.

---

9 In relation to the evaluation process, N.B. Rancich, Notas sobre a avaliação da pós-graduação, CAPES/Coordenação de Avaliação, Brasília, August, 1982, points out that the concept of a post-graduate course allows is to be situated in a given scale, as a result of a comparative analysis of one course with the others in a given field of knowledge. It is graded in a value scale from A to E, where A represents the best evaluation and E a situation where the course does not fulfill the necessary criteria. The concept is derived from an analysis of multiple indicators and considers not only the evolution, in time, of the course, but also its evolutionary stage. CAPES evaluation process is done by prominent researchers in a given field, through the peer review system.

10 It implies that the greatest number of researchers on CNPq fellowships are concentrated in the Southeast (73% or 169), mainly at São Paulo (63.4% or 104). Concerning the scientific production, M.A.H. Cagnin, O Desenvolvimento Regional a e Participação do Pesquisador Químico no Progresso Científico da Química Brasileira, *Química Nova* 10 (1987), 223, has shown that, of the 73.3% of scientific publications in Organic Chemistry and 83% of scientific publications in Physical Chemistry, Inorganic Chemistry and Analytical Chemistry, that were produced in the Southeastern Region during the 70's, the production of USP alone represented 40.5% of the former group, and 41.6% of the latter.

11 An advisor/student ratio considered as fair is 1.0/5.0, see N. B. Rancich, op. cit. note 8.

12 This seems to be a general tendency of the Brazilian post-graduate programmes, as stressed the study of the Commission of the Scientific Societies, Documento sobre Ciência e Tecnologia na Nova República, *Ciência e Cultura*, 37 (1985) 1879.

13 For details see National Research Council, Opportunities in Chemistry; Committee to Survey opportunities in the Chemical Sciences, National Academy Press, Washington D.C., 1985.

Table 6. Main factors that increase the efficiency of research and postgraduate activities in chemistry by region

Category of Analysis	North		C.West		Northeast		Southeast		South	
Factor	#pts	%	#pts	%	#pts	%	#pts	%	#pts	%
Intel. Capital										
Qualities of researchers	14	20.4	13	25.0	28	20.9	74	17.7	32	20.7
Partic.of students	-	-	7	13.5	8	6.0	42	10.0	16	10.3
Post-grad. degree holders	5	10.2	3	5.8	16	11.9	4	1.0	9	5.8
motiv. working atmosphere	6	12.2	-	-	-	-	26	6.2	9	5.8
Collaborations in the country	4	8.2	-	-	22	16.4	27	6.5	18	11.6
Nb. of qualified R.	-	-	-	-	10	7.5	12	2.9	10	6.4
Collaborations with other countr.	-	-	-	-	-	-	11	2.6	-	-
Participation in congresses	1	2.0	-	-	1	0.7	2	0.5	-	-
Infrastructure										
Equip & Lab infrastruct.	8	16.3	6	11.5	7	5.2	31	7.4	2	1.3
Avail/Access to bibliogr.	-	-	7	13.5	3	2.2	16	3.8	8	5.2
Technical support	-	-	-	-	-	-	16	3.8	-	-
Physical space	6	12.2	-	-	2	1.5	-	-	1	0.7
Computer res.	-	-	1	1.9	5	3.7	-	-	-	-
Support Dynam of dept.	2	4.1	6	11.5	5	3.7	-	-	5	3.2
Investment										
Availability of budgetary res.	-	-	3	5.8	-	-	-	-	-	-
Availability of budgetary extramural res.	5	10.2	3	5.8	7	5.2	67	16.0	16	10.3
Availability of scholarships	-	-	-	-	7	5.2	16	3.8	-	-
Research at low costs	-	-	-	-	-	-	10	2.4	1	0.4
Applied Research	-	-	-	-	7	5.2	-	-	8	5.2
International Coop.	-	-	-	-	-	-	-	-	6	3.9
Others	2	4.1	3	5.8	4	3.0	48	11.5	7	4.5
TOTAL	49	100.0	52	100.0	134	100.0	418	100.0	155	100.0

Even though the post-graduate courses in Chemistry, present a poor level of performance, when compared to other courses we discover some positive features: in December 1986, the post-graduate courses in Physics employed 927 Doctor/faculty-members, and there were 1291 students attending such courses[14], which gives us a student/advisor ratio of 1.0/1.39. Their idle capacity is therefore very great. To this we should add that, while in Chemistry the great majority of faculty members are involved in experimental research -and that there is indeed a lack of Theoretical Chemists whose role will be of increasing importance in the future development of Chemistry research, according to prospective studies from the European Chemical industry, especially in the sector of pharmaceuticals, dyes and fragrances[15]- in Physics, 52% of the faculty-members are Theoretical Physicists[16]. This distortion, even though it may appear to favour scientific production in Physics[17], since experimental work takes longer, and is often more costly to produce than theoretical work, must raise a question that merits further analysis; Brazilian Physics theoretical research may be too much dependent on foreign inputs[18].

Infrastructure

Table 5 clearly shows that in all the regions of the country the major obstacles to RPG can be attributed to poor infrastructure. There are, however, a few groups (one from the Central-West -Brasilia's Organic Chemistry- and three from the Southeast -São Paulo's Organic and Physical Chemistry, and to a lesser extent, Rio de Janeiro's Analytical Chemistry) with a better quality of infrastructure. These groups are responsible for the Good responses when asked to rate the quality of their laboratories and equipment (Tables 3 and 4), and for listing it as one of the positive factors promoting efficiency in RPG (Table 6).

The lowest grades attributed to infrastructure in the Central-Western Region come mainly from the Federal University of Mato Grosso do Sul (UFMGS), which is the newest institution to be involved in research activities (basically Organic Chemistry), and where the greatest obstacle is the lack of scientific equipment (Table 6).

The worst ratings for infrastructure come from the Northeast, the South and certain areas of the Southeast[19] (especially from the state of Minas Gerais). Such

---

14 According to the Report of the Brazilian Physics Society (SBF), Física no Brasil, 1987.

15 U. Colombo, Research, Innovation and Renewal in the Chemical Industry, *Futures*, April (1986) 170.

16 SBF, op. cit. note 13.

17 M.A.H.Cagnin, Patterns of Research in Chemistry in Brazil, *Interciencia*, 10(1985) 64.

18 J. Danon, Depoimento 1977, Convênio FINEP/CPDOC - História da Ciência, FGV/CPDOC, Rio de Janeiro (1985) 63.

19 The scientific conditions for research within the Southeast are uneven, and the discrepancies between the Northeast and the Southeast are less significant if the State of

precarious conditions of Chemistry research are even more striking when one considers that, among the five main factors given as being favourable to RPG, infrastructure is not included (Table 6). The brief mentions that we get to this factor relate to facilities that can be borrowed from neighbouring institutions (distances are not mentioned) and references are made to efforts underway in these institutions to improve their own facilities.

There seems to be a contradiction in the evaluations received from the Northern region, since on the one hand infrastructure is rated as being Fair in the general sense (Table 3) and also when the component items are being examined. However, infrastructure is cited as one of the obstacles to a more efficient RPG (in Table 5). This contradiction is apparent again when we compare Table 5 with Table 6.

The poor availability of imported materials was perceived as being Very Bad by 36% of the respondents, and as Bad by another 39%, and this was further exacerbated when the maintenance of imported equipment was discussed; the problem of maintenance was rated as being Very Bad or Bad by 86% of those surveyed. This last factor was of greatest concern to those researchers from the Southeast, since they were the most privileged ones with regard to the availability of such equipment for the performance of their work (Table 5). One exception to the problem of availability of imported materials is the University of Brasilia (UnB), which enjoyed certain legal privileges that were not extended to other research institutions (it is allowed to use a more favourable exchange rate and the need for an imported license is waived)[20].

In short, at the most advanced research institutions, those which are the best equipped, there is greater awareness of the limitations with regard to scientific development, but it is precisely at these institutions that we heard the greatest number, and the greatest intensity of criticisms with respect to working conditions. Paradoxically, the groups of researchers who work at the most rudimentary and precarious conditions seem to have full consciousness of what little support structure they have available and, rather than seeing it as an obstacle, regard any facilities that they do have as a positive factor that contributes to their work.

From what was shown, the main bottleneck seems to be the lack of resources to be directed towards the improvement and maintenance of a ever more

---

São Paulo is treated separately. Many facts appeared when comparing the evaluations of the items in Topic 1, considering the researcher and the state in which he/she worked. For example, the item regarding equipment for RPG was rated, on average, as Fair in São Paulo, near Bad in Rio de Janeiro, and Bad in Minas Gerais just as in the whole of the Northeast.

[20] After several years of continuous pressures of the scientific community, mainly through the Brazilian Society for the Progress of Science (SBPC), the National Congress approved in April 2, 1990 the Law Nº 8010 which removes taxes on imports of machines, equipment and material for scientific ends, and this includes accessories, replacement parts, raw materials and intermediate products for all those institutions listed by CNPq. The results are not still felt over the system.

developed infrastructure, that is a fundamental requirement for competitive RPG. To get better research facilities it is necessary that the National and the state Assemblies recognize that there is an urgent need of a special credit line for Programmes involving the creation, maintenance and modernization of research laboratories, outside the ordinary funding mechanisms[21] (which also need to be increased). Unless such measures are taken, the number and type of institutional and individual worthy research projects will continue to be subject to restrictions, and this in turn will contribute to the loss of qualified researchers who are attracted abroad by the better facilities and conditions offered by foreign research institutions.

Investments

Even though the researchers attributed a low relative value to investments in the second and third questions (Tables 5 and 6, respectively) when the matter was approached directly, as in the first question, they were rated as Fair by researchers in the North, Southeast and South of the country, and as Bad by those in the Northeast and Central-West (Table 3).

The situation appears to be most critical in the Northeast since the researchers from that region gave the worst possible rating, Very Bad, in their evaluation of the financial support for their research institutions, and also of the extra-budgetary resources derived from federal funding agencies. The lack of the latter was seen as being as great an obstacle to research as was the lack of scientific instruments (Table 5). In the Northeast the only exceptions to this rule are the departments of Organic Chemistry, at the Federal University of Ceará (UFCe), Physical Chemistry at the Federal University of Pernambuco (UFPe), and Inorganic Chemistry, at the Federal University of Paraíba (UFPb), which rated investments as Fair.

We find that it is in these same universities that CNPq invests the most, using such mechanisms as research-fellowships, which are the best individual reward it has to offer[22]. Thus the higher evaluation ratings given for investments in these

---

[21] It happens even in industrialized countries. See, D. Hanson, Many University Research Facilities Need Repairs, *Chemical and Engineering News*, November 14 (1988) 42.

[22] Of the fellowships awarded for Chemistry by CNPq in the Northeastern Region, 15%, 8%, and 45% of them are respectively centered on UFPe, UFPb and UFCe [While the first two institutions established post-graduate programmes in the second half of the 80's, UFCe's dated from the 70's and is considered an excellent course, even though its scientific production per capita is equal to that of UnB, whose course was evaluated as Good]. As described in M.A.H. Cagnin, op. cit. note 16, the Northeast is the third most prolific scientific producer in the country. Its contribution in the 70's was around 7%, which was very close to the second, the South (7.5%), but far behind the first, the Southeast.

institutions must reflect their recognition of the support lent by CNPq through the peer review system[23].

In Chemistry departments of the Southern Region we find an emphasis that is very similar to what we observed in the Northeast in relation to the barriers that have their origin in the lack of institutional support. The only two groups which gave more favourable ratings with regard to investments were the Physical Chemistry and Organic Chemistry groups (Tables 3 and 4) of the Federal University of Santa Catarina (UFSC). Most of the Chemistry researchers on CNPq fellowships in the Southern region were centered on UFSC[24]. Thus, once again, a relationship can be perceived between CNPq activities and researchers' responses.

Close examination of researchers' answers leads us to conclude that the average conditions for RPG with regard to Intellectual Capital and to Infrastructure are similar in the Northeastern and Southern regions of the country. When it comes to Investments, however, the situation in the South is deemed to be better. Both in the South and in the Northeast, Investments, in the form of extra-budgetary funds, are considered to be a crucial factor for the promotion of the efficiency of RPG (Table 6).

CNPq's and Finep's performance were rated as Very Bad or Bad, respectively, by 40% and 63% of the respondents. An explanation for those low ratings is that science is dependent on governmental funding agencies and very few resources have been driven to chemical research. Concerning, for instance, the individual CNPq research grants for Physical and Earth-Sciences in the 1951/84 period enjoyed a growth rate 3.6 times greater than Chemistry, 3.9 times greater than Geo-Sciences, and 6.5 times greater than Mathematics[25]. In recent years, CNPq relative contribution to chemistry research among the "hard sciences" decreased[26] as shown in Table 7.

Referring to human resources capacitation, the 85% increase in the 1986/1988 period in the number of CNPq scholarships distributed nationwide, hardly affected the relative support to Chemistry which remained around 5% of the total. Regarding overseas scholarships granted to chemists, whereas the number remained stagnant, the total number of scholarships offered by CNPq rose by

---

23 CNPq Advisory Committees are formed by prominent researchers selected with the participation of the respective academic communities.

24 If the different kinds of support CNPq has given to the Southern Region since 1976, it is observed that between 53% and 66% of the fellowships were awarded to UFSC.

25 M.A.H. Cagnin, D.H. da Silva, *A Ação de Fomento na História do CNPq*, Assessoria Editorial, CNPq, Brasília, 1987.

26 In 1987, CNPq total budget for supporting its research grants programme totalized US$ 31,420 million. Around 30% were directed to fund Physical and Earth Sciences projects.

112% in the 1986/1988 period, which means that there was a relative decrease of 1.7% for chemical studies abroad[27].

Table 7. Relative distribution of resources in the fields of physical and earth-sciences research grants programme, in the 1980's.

FIELD	1981/1984 (%)	1987 (%)	1988 (%)
Physics	44.0	44.1	36.7
Chemistry	24.8	19.3	19.3
Mathematics	11.8	21.5	29.4
Geosciences	19.4	15.1	14.6

Source: Cagnin and Silva, 1987, Activities Report 1988 - CNPq

Within the scope of Finep, which is to provide institutional support for infrastructure, new buildings and new equipment, through the National Science and Technology Development Fund, Table 8 shows the priority given to Chemistry recently[28].

Table 8. Relative distribution of FINEP's Institutional grants in the field of physical and earth sciences, in the late 1980's.

FIELD	1986 (%)	1987 (%)	1988 (%)
Physics	61.8	58.7	58.8
Chemistry	20.5	21.0	26.2
Mathematics	4.3	10.1	4.3
Geosciences	13.4	10.2	10.7

Source: Activities Report 1988 - FINEP

Therefore, the federal investment in Chemistry is meagre, reinforcing the reasons why researchers in this field gave the agencies such low ratings in their answers to the questionnaire. This picture is not more dramatic due to the Programme of Support for Scientific and Technological Development (PADCT)[29], whose aim is to complement the ordinary channels of support, by

---

27 For the scholarships programme, CNPq total budget summed up US$ 118,343 million, which meant the distribution of 20.146 scholarships inside the country, and 1.307 overseas. For Chemistry, CNPq provided 949 scholarships of the first group, and 51 of the second.

28 25% from a total budget of US$107 million were allocated to Physical and Earth Sciences, in 1987 by FINEP (the Agency for Financing Studies and Projects).

29 The PADCT Fund is composed by a sectorial World Bank loan of US$72 millions plus the Brazilian government counterpart of US$ 108 millions. Out of this total amount, US$32 millions were allocated to Chemistry and Chemical Engineering for the 1984/1989 period.

inducing demand for specific projects. But this programme is not a sufficient alternative to the traditional incentives.

A perusal to Table 5 shows that the researchers from the most developed centers in the Southeast are those who express the greatest concern with regard to the negative effect of a weak financing system for research, and that they see this factor as being of even greater worry than the problem of the lack of resources. These researchers, together with the Northeastern group, are the ones who stress that the lack of a clear, long-term policy of support for research, which encompasses the regional question, is a great hindrance to RPG.

It is because of the lack of such a policy that many groups of researchers find themselves obliged to leave aside their research activities and take on administrative duties in organizations such as the Brazilian Society for the Progress of Science and the Commission of the Scientific Societies, to lobby the Executive and Legislative branches of the government and persuade them of the importance of science as an investment item, rather than a consumption item, which is how it has so often been perceived in underdeveloped countries[30]. Even with such a pressure, the available resources are so scarce that they are used in a stop-gap manner, so as to cover the permanent past shortcomings. As a result, it is a challenge to sort out priorities either at the level of the federal sponsoring agencies, or at the level of the internal bureaucracies of the universities.

In the case of Chemistry, due to its multiple linkage with the general economic activity and the well-being of the population, the non-existence of a scientific and technological policy linked with an industrial planning is a deep drawback to its progress, still to be overcome.

In Brazil, the chemical industries participate with around 5% of the GNP[31]. They constitute the largest industrial complex in Latin America and the Caribbean Region, being also among the biggest ten worldwide[32]. On the one hand, these industries are mainly owned by foreign companies, and they are generally polluting, based on obsolete technologies, and carry out most of their research and development abroad. On the other hand, the low profits of the local firms inhibit investments, and they do little and, in general, unsophisticated research. Thus, jobs, especially for graduated people, are neither numerous nor attractive in terms of professional accomplishment. Therefore, enhancing a greater chemical development would necesitate the growth of those segments of the chemical industry where science and technology are required, such as fine chemicals and specialties. Thus, research and post-graduate activities in Chemistry would naturally be affected. This would modify the isolated system that now prevails, which produces highly qualified human capital for an almost exclusive but finite market-job: universities and government research institutes.

---

30 C. Cooper, Science, Technology and Production in the Underdeveloped Countries: An Introduction, *The Journal of Development Studies*, 9 (1972) 1.

31 PADCT, Subprograma de Química e Engenharia Química, Documento Básico, June, 1990.

32 PADCT, op. cit. note 30.

In order to transpose this scenario where science is totally dependent on government and strengthen the ties between science and production, besides the recommendations contained in Cagnin[33], with some of them already incorporating the 1988 new constitutional text, the following measures are here placed:

The Chemical companies operating in the country ought to open a formal and systematic programme of support for research in Chemistry. One way of implementing it would be through their participation in the current science and technology programmes sponsored by the federal and state agencies, as it is done in other countries[34]. Such participation could be structured along the lines of agreements between CNPq/industry, or Finep/industry, and should include funds, equipment, and trained personnel for research projects that are of common interest to the different parties, whether in basic or applied science.

If these suggestions can be implemented, the next step in the middle term, shall be the creation of new research centres, where there will be a large-scale cooperation between industry and university[35], within a triple alliance of university, industry, and the sponsoring agency (the latter would have a role of decreasing importance with the passing of time).

It should be emphazised that the implementation of such measures is greatly dependent on political power, economic stability, and governmental regulations.

CONCLUSION

The survey of Chemistry researchers shows that the conditions for development of this field of science have been far from ideal. Although the quality of the research produced in post-graduate activities is reasonable, the small number of people involved in Chemistry, and the precarious conditions in which they work -the poor quality, the obsolescence and lack of maintenance of research facilities- are serious constraints. The vitality of Chemistry research is still hampered by the complex redtape to import scientific materials.

The environment in which Chemistry research is carried out is, of course, reflected in the scientific production of the country. Brazil is Latin America's leading producer of Chemical research[36], and of scientific research in general[37].

---

33 M.A.H. Cagnin, Química e Desenvolvimento Nacional, *Revista Brasileira de Tecnologia*, 18 (1987) 10.

34 J. Long, Industrial Role in NSF Program Growing, *Chemical and Engineering News*, Sept. 4 (1989, 16).

35 J. Long, op. cit. note 33.

36 M.A.H. Cagnin, op. cit. note 16.

37 M. Krauskopf, R. Pessot, R. Vicuna, Science in Latin America. How much and along what lines?, *Scientometrics*, 10 (1986) 199.

Chemical research generated fewer papers than Physics in Brazil, while worldwide, Chemistry produces more papers than Physics[38].

The poor amount of resources available for research and to training of human resources in Chemistry is a serious bottleneck, and is further exacerbated by the little influence that Chemists appear to have within the brazilian Science and Technology funding system. In addition, the lack of linkages between university and industry means that research is carried out in an atmosphere that is completely divorced from market pressures and society in general. Another evident concern is the uneven rates of development in Chemistry in different regions of the country, reinforcing the inequality of the centre vs the periphery within the country itself.

These elements clearly reveal that a process of change must take place in order to break the vicious and self-perpetuating circle of the poor and backward conditions under which scientific research is carried out. The focus of this process must be the formal recognition by government of the important role that Chemistry has to play in Brazil's social and economic development. The participation of the scientific community, together with the technicians and entrepreneurs of the Chemistry sector is vital in this process, because they themselves must be not only the agents of change but also those who should have the responsibility for providing inputs to decision-makers on the best strategies for promoting this development.

The deep economic crisis that Brazil is facing and the absence of a formal policy for the endogenous development of Chemistry, make it imperative that we begin now to build new options for the future, starting from the best diagnosis as possible, and taking into consideration not only the direct variables and those factors which appear to dominate the scenario in which Chemistry is conducted, but also the alternative possibilities for integrating Chemistry into the general context of the Brazilian society. This is a challenge which must be faced, and which brings to mind that "the solution of the apparently insoluble problems of developing countries, namely unemployment, poverty, and hunger, requires a significant and critical input from chemical science and technology"[39].

---

38 D. Solla Price, Nations Can Publish or Perish, Science and Technology for Technical Men in Management, October (1967) 84; National Science Foundation, Science Indicators 1982. An Analysis of the State of US Science, Engineering and Technology. National Science Board, Washington D.C. (1983) 203.

39 H. Szmant, Chemistry - a tool of socio-economic progress. *Ciência e Cultura*, 34 (1982) 892.

Aknowledgments

the author is thankful to CNPq, which allowed her to be on leave of absence to the Institute for Advanced Studies of the University of São Paulo, where this study was developed, and to the Ford Foundation for the post-doctoral fellowship granted. Critical comments from Léa Velho were very much appreciated.