

Journal of Business Chemistry

Vol. 3, Iss. 2

May 2006

How Do Italian Biotech Startups Survive?

Anna Nosella, Giorgio Petroni, and Chiara Verbano

Detergent Phosphates: an EU Policy Assessment

Jonathan Köhler

Chemische Fabrik Griesheim - Pioneer of Electrochemistry

Dieter Wagner

www.businesschemistry.org

EDITORIAL BOARD

Editor-in-Chief

Dr. Jens Leker, Professor of Business Administration in the Natural Sciences, University of Münster, Germany

Executive Editors

Lars Hahn,
Benjamin Niedergassel,
Stefan Picker,
Prof. Dr. Stefan Seeger,
Dr. Carsten Vehring

Language Editor

Madeleine Vala, PhD

SUBSCRIPTION

The Journal of Business Chemistry (Print ISSN 1613-9615, Online ISSN 1613-9623) is published every four months by the Institute of Business Administration at the Department of Chemistry and Pharmacy, University of Münster.

Online-Subscription is possible at subscription@businesschemistry.org. Free download is available at www.businesschemistry.org.

AIMS AND SCOPE

The *Journal of Business Chemistry* examines issues associated with leadership and management for chemists and managers in chemical research or industry. This journal is devoted to the improvement and development of the field of Business Chemistry.

The *Journal of Business Chemistry* offers a means for researchers and practitioners to present their results in an international forum.

ABSTRACTING AND INDEXING

Journal of Business Chemistry is covered by the following abstracting and indexing services:

- EBSCO Publishing (www.ebsco.com)
- Hamburg Institute of International Economics (online databases and print archive)
- German National Library of Economics
- Swets Information Services

COPYRIGHT

Copyright © 2006 Institute of Business Administration, University of Münster

All Rights Reserved. No part of this publication may be reproduced or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, scanning or otherwise, except as described below without the permission in writing of the Publisher.

Copying of articles is not permitted except for personal and internal use, to the extent permitted by national copyright law. Requests for permission should be addressed to the publisher.

Statements and opinions expressed in the articles and essays are those of the individual contributors and not the statements and opinions of the Institute of Business Administration, University of Münster. The Institute and the University of Münster assume no responsibility or liability for any damage or injury to persons or property arising out of the use of any materials, instructions, methods or ideas contained herein. The Institute and the University of Münster, expressly disclaims any implied warranties or merchantability or fitness for a particular purpose. If expert assistance is required, the services of a competent professional person should be sought.

SERVICES

For advertisement please contact: contact@businesschemistry.org

PUBLISHER

The Journal of Business Chemistry (ISSN 1613-9615) is published by the Institute of Business Administration at the Department of Chemistry and Pharmacy, Westfälische Wilhelms-University, Leonardo-Campus 1, 48149 Münster, Germany.

Contents

Letter from the Editors

Commentary

- School for the Bilingual: Dual Master's Degrees in Business and Biotech*
Emily Waltz.....3

Research Paper

- How Do Italian Biotechnology Startups Survive?*
Anna Nosella, Giorgio Petroni, Chiara Verbano.....7
- Detergent Phosphates: an EU Policy Assessment*
Jonathan Köhler.....15

Practitioner's Section

- Chemische Fabrik Griesheim – Pioneer of Electrochemistry*
Dieter Wagner.....31

Erratum

Letter from the Editors

Interdisciplinarity at Work

In a world of increasing specialization in all fields of science and business, interdisciplinary approaches become ever more important for researchers and practitioners alike. The *Journal of Business Chemistry* – now published for two years – is devoted to this interdisciplinary context, bringing together research and business-related contributions from chemistry, biotechnology and pharmaceutical sciences.

In this May of 2006 we do not only celebrate two successful years of the *Journal of Business Chemistry*, but also the 70th birthday of a person whose academic life was dedicated to domain spanning research and management: Prof. Dr. Dr. h.c. Jürgen Hauschildt, one of the most renowned researchers in German business administration and innovation management. Prof. Hauschildt has expertise in many disciplines, ranging from financing and accounting to innovation management. He always succeeded to integrate academic research with practical managerial implications – even in very complex and theoretical fields. His life's work is the innovation management where he made major contributions in many fields, two well-known examples being the promotor model [1, 2] and the innovation success and degree of innovativeness [3, 4]. The editors of the *Journal of Business Chemistry* congratulate him to his birthday and wish him all the best.

For this Vol. 3 (2) of the *Journal of Business Chemistry* we would also like to thank the authors and contributors of the articles and commentaries. Again we have a broad and interdisciplinary bundle of interesting papers, ranging from management of SMEs in biotechnology to the importance of innovations in the history of a chemical company.

Special thanks go to our Language Editor Madeleine Vala, who greatly supported us. Due to a new job position she will no longer be available as a language reviewer. We also welcome two new editors: Prof. Dr. Stefan Seeger and Benjamin Niedergassel.

Now enjoy reading this second issue of the *Journal of Business Chemistry* in 2006. If you have any comments or suggestions, please send us an e-mail to contact@businesschemistry.org.

Stefan Picker
Benjamin Niedergassel
Prof. Dr. Jens Leker

- [1.] Hauschildt, J. (2004). *Innovationsmanagement*. 3rd ed. München, Germany: Verlag Franz Vahlen.
- [2.] Hauschildt, J., *Promotors and champions in innovations - development of a research paradigm*, in *The Dynamics of Innovation*, K. Brockhoff, A.K. Chakrabarti, and J. Hauschildt, Editors. 1999, Springer: Heidelberg.
- [3.] Hauschildt, J. and T.M. Schlaak (2001). *Zur Messung des Innovationsgrades neuartiger Produkte*. Zeitschrift für Betriebswirtschaftslehre, 71(2): p. 161-182.
- [4.] Hauschildt, J. (1991). *Zur Messung des Innovationserfolges*. Zeitschrift für Betriebswirtschaft, 61: p. 451-476.

Commentary

School for the Bilingual: Dual Master's Degrees in Business and Biotech

Emily Waltz^{*#}

* Freelance journalist, New York

Correspondence to: emwaltz@hotmail.com

Abstract: Advanced degrees that combine a master's in business with a master's in biotechnology are popping up at a number of universities. The programs aim to churn out students who will bridge the gap between scientists and managers at biotech companies. This article explores these dual degrees, the students' skills when they graduate and what they can do for the biotech industry.

Introduction

Biotech industry experts have long lamented the gap between scientists and business managers at many companies. Academia who build start-ups based on their research discoveries often have no idea how to run a business. Managers often don't fully understand the science behind their companies' products [1]. Communication between the groups gets mired in the jargon of both fields.

Government officials and industry executives have called for universities to produce students with both science and management expertise [2]. Students have also demanded an option for a dual degree. In response, schools are developing dual-degree master's programs that combine business and biotech. So far, the programs only accept a handful of students each year, but most say their rosters are growing.

The first students to enroll in the programs are graduating now, and companies are hoping they will bring new and versatile talent to the biotech workforce. Local governments hope the students will boost budding biotech clusters and local economies.

True, a few semesters of grad-level courses hardly makes a scientist out of businessperson, or a manager out of a researcher. And no textbook can teach the nuances of schmoozing necessary for making business deals. But the first recipients of these degrees are advancing their careers and building startups. Whether they could have done it without spending tens of thousands of dollars on advanced education, we may never know.

The curriculum

The purpose of almost any business-of-science program is to teach students to think beyond the academic world and to be more business-minded. Students should understand how to turn technology into products and to how to communicate complicated ideas to non-specialized audiences. But accomplishing this in the academic environment can be tough.

University administrators say admitting the right students is the key. Applicants who are passionate about both business and science and who have somehow noticed the gap that exists between scientists and executives are the most promising.

University of Pennsylvania initiated its dual degree program in 2003 after administrators noticed that many students in the business school were enrolling in biotech courses or getting second master's in a science field, says Scott Diamond, director of Penn's biotechnology program.

But many people have talent in one area or the other, not both, say program directors. Others are not far enough along in their careers to realize the importance of having expertise in both areas. To sift through the applicants, some schools look for those with work experience and an undergraduate degree in science. For example, RMIT in Melbourne, Australia requires a degree in a science field and at least three years of industry work experience.

Dual degrees can take anywhere from one to three years and up to more than 60 courses to complete, depending on the university. Most programs offer a part-time schedule for employed people who want to keep their jobs.

The courses teach skills such as how to manage a team, patent a discovery, balance risk and network with investors. Students also spend time in the lab studying molecular biology and biochemistry.

Some of the more interactive programs place students in internships. Others hire industry executives and investors as guest lecturers. The University of Calgary in Alberta, Canada brings in biotech experts every week to have lunch with the students [3].

Interaction with local economies.

When biotech executives and government officials complain about a weak talent pool of business-savvy scientists, they have their own businesses in mind [4]. And schools are listening to their grumblings.

Calgary gears its curriculum toward the needs of industry, says Derrick Rancourt, a coordinator of the university's biotech program. "We thought it would strengthen the local economy if we created some expertise in the area," he says.

Recruiters often try to fill entry-level positions with graduates from nearby schools. Because they depend on these graduates, they sometimes help plan courses or create internships for them.

The State University of New York in its Brooklyn location hosts a biotech incubator where fledgling companies—most of which were started by the school's faculty—rent space for their start-ups. Some of the companies offer internships for students in the dual degree program.

Many programs are geared for part-time students working locally who want to switch from the bench to management or seek a promotion. Other programs focus on entrepreneurship and help students build start-ups headquartered locally and elsewhere.

Countries and cities with an entrepreneurial culture will likely produce more business-minded scientists, says O. Prem Das, director of technology development at Harvard Medical School. Australia, a country that strongly values entrepreneurship, is home to a significant portion of universities that offer either a dual degree or some kind of business component in their biotech programs.

Cities known for their biotech clusters can also generate interest in the field. For example, the University of California hosts its dual degree program in San Francisco, one of the largest biotech clusters in the world.

Will the programs fill the void?

When students graduate from dual degree programs, they want to have acquired a business sense that matches their lab expertise, along with contacts in the industry. But can academics teach students not to be so, well, academic?

Time devoted to education allows entrepreneurs to slow down and take a few years to observe the field. School allows them to take

the time to make thoughtful decisions on who they want to work with and which technologies to pursue.

But clearly, a few courses in basic science can't replace the bench experience aspiring researchers would receive in a post doctoral position. Likewise, class time could never rival experience gained through personal relationships with people in the business.

True, some universities are making efforts to connect students to investors, intellectual property lawyers and executives. What these introductions accomplish is difficult to measure.

Students who build start-ups using the investors they met in school are evidence of success. But no amount of networking or lab time will mold students to love the business of science. A student must have the entrepreneurial bug—or at least a knack for managing—to translate an idea into a product.

References

- [1] Gewin, V (2005), Making it in the biotech business. *Nature*, 435: p. 124-125
- [2] NAS (1995), Reshaping the Graduate Education of Scientists and Engineers, *National Academy of Sciences*: Washington D.C.
- [3] Waltz, E. (2005) Biotech entrepreneur, educate thyself! *Nature Biotechnology*, published online 15 December 2005
- [4] Fox, J. (2001) Bush's biotech bent. *Nature Biotechnology*, 19: p. 97

Research Paper

How Do Italian Biotechnology Startups Survive?

Anna Nosella^{*}, Giorgio Petroni^{*} and Chiara Verbano^{*#}

* Dip. Tecnica e Gestione dei Sistemi Industriali, Università degli Studi di Padova, Str.lla San Nicola 3, 36100
Vicenza, Italy

Correspondence to: chiara.verbano@unipd.it

Abstract: This study was carried out in order to better understand the economic and managerial characteristics of the biotechnology industry, which has taken hold in Italy at a much slower rate than in other industrialized countries. In particular, the specific aims of this paper are to analyse the business models of new Italian biopharmaceutical firms and to examine how these firms, with their different business models, successfully overcome the initial stage of starting up. On the basis of interviews conducted with sector experts and managers, we will conclude that the success factors behind the startups comprise a diverse range of distinct competencies that depend on the type of business model adopted.

Introduction

Biotechnology is one of the most significant emerging technologies and generates many applications in different fields, such as healthcare, agriculture, the food industry, fine chemistry and the environment.

The biotechnology industry was pioneered in the United States where small biotechnology firms were started up in the early 1980s; the development of the biotechnology industry, however, has not been uniform in all countries. In Europe, with the sole exception of the United Kingdom, the business of biotechnologies developed much later than in the United States due to the following main reasons [1, 2]:

- The problem of finding financing for these new firms (in particular the absence of a structured venture capital system)
- The limited protection guaranteed by the patents system
- The weak relationship between Academia and Industry, which complicates the knowledge transfer process
- The fragmentation and specialization of research.

As in other European countries, the development of the biotechnology industry has taken hold in Italy only recently; in fact, even though there is a good level of scientific and technical competency, particularly in the pharmaceutical industry [3], the factors mentioned above have delayed growth.

In the pharmaceutical sector, in particular, biotechnology is doomed to undergo a revolution that will change the industry's structure: on one hand a process of concentration of large firms has begun to take place and on the other hand new small biotechnology firms specialising in a particular discipline or research activity have been launched.

As a consequence, the biopharmaceutical sector is organized as a network made up of universities, public and private research centres, small biotechnology companies and large consolidated

companies all working in collaboration rather than in competition.

The first aim of this paper is to analyse the different business models adopted by the companies that constitute this network; in identifying this taxonomy of business models, particular attention was paid both to the value chain activities of these companies and to the products and services they exchange with the market. We expected some of the critical factors for competition to depend on the type of business model adopted. The second aim of this paper is to analyse the following issue: for each of the business models identified, we have examined one biopharmaceutical startup firm in order to study the critical factors that have allowed it to survive and compete in this context. In other words, we are interested in examining how new biopharmaceutical firms with different business models successfully overcome the initial stage of starting up.

In order to identify the business models adopted by biotechnology companies, we first analysed the specialised literature [4, 5] and then confirmed the results obtained from the literature review by interviewing some sector experts (e.g. the head of the National Association for the Development of Biotechnology).

Concerning the second objective of the study, which was to analyse the success factors of biopharmaceutical firms, we conducted eight interviews both with the CEO of these firms and with their R&D managers. The main topics discussed regarded:

- The firm's history: particular attention was given to the problem of finding financing
- The firm's offering: type of products/services, characteristics of the pipeline, production strategy (internal manufacturing/outsourcing/licensing), type of distribution
- Market factors: nature of the market (local, national or international), position of the customer in the value chain, market breadth
- Internal capability factors: the source of internal competence was identified

- Competitive strategy factors: the position of the firms in the competitive arena was analysed
- Innovative performance of the firm: trend of R&D investments, number of patents obtained, trend of employees, number of products/ processes/ services being employed.

The Business Models of Biopharmaceutical Companies

Biotechnology has contributed to a change in the pharmaceutical sector in both the internal processes and the external industrial structure [4]. Concerning the former, the use of biotechnology has modified the research methodology and the production processes.

Concerning the latter, biotechnology has changed the role played by pharmaceutical companies by creating a network of firms specialized in different activities along the value chain. Consequently, the pharmaceutical industry has taken a new configuration: while until the late eighties the sector was constituted by large vertically integrated companies, now it comprises a system of companies specialized in a particular stage of the innovative process, in a particular discipline, or in supplying services. The structure of this industry has become more complex and consequently different business models are adopted by biopharmaceutical firms. One of the aims of this paper is to suggest a taxonomy of these different business models on the basis of literature analysis [4,5] and the interviews conducted.

Five different business models were identified:

- New biotechnology firms: typically carry out research activities until lead optimisation, and then license their outputs (i.e. drug candidates) to other firms
- Integrated firms: have a strong pipeline and carry out all the primary activities of the value chain, from target identification or lead optimisation to product commercialization. They thus cover the research and development phase, pre-clinical and clinical development, the post-approval phase, and production and commercialization activities
- Manufacturing companies: typically acquire the results of the research carried out by other companies and dedicate their efforts to the latter phases of the innovative process by carrying out engineering, production and commercialization activities
- Biotech suppliers: are firms that carry out the industrial development and production of biotech products for other firms. These companies use biotechnology in the production process in order to obtain biological products, such as monoclonal antibodies, cells and proteins, and supply them to other biotechnological companies. They develop production processes often in collaboration with customers and end their role with the supply of the product
- Services firms: sell research services such as chemical synthesis, the study of cloning, and sequencing to drug-oriented companies that want to enhance their organisational competences. The startup capital required from this type of firm is smaller than that required by the previous business models.

Literature analysis enabled us to recognize the following business models: new biotechnology firms, integrated firms, manufacturing firms and service firms. We decided to exclude platform firms (also identified in the cited literature) because their core business is constituted by developing and commercializing technologies (i.e. physical devices and software tools) to support the R&D process behind new drugs. The business model represented by biotech suppliers was identified through the interviews that at the same time were also used in order to confirm the previous business models.

After identifying this taxonomy, we selected one Italian startup firm for each of the aforementioned business models with the aim of analysing the success factors which have allowed them to overcome the startup stage. The firms selected were the following:

- **Company A**, founded in 1998 from a previous industrial unit, is a new biotechnology firm (NBF) whose core business is focused on discovery and preclinical development stages. While this study was being carried out, the firm was involved in a merger process.
- **Company B** was founded in 1996 after a “management buyout” with the aim of becoming an integrated firm. It operates in all value chain activities, from the research stage to product manufacture and commercialization. When this study was being carried out, the firm had already built the production plant, but it still hadn’t set up a network for commercializing its own products (which were currently in the second clinical stage).
- **Company C**, founded in 1999, is a firm that carries out customized production for other companies. It uses biotechnology as a production methodology in order to develop biological products such as cells and monoclonal antibodies.
- **Company D**, founded in 2001, provides services (such as sequencing, diagnostic tests, training, etc.) in the field of diagnostics and research to firms belonging to different industries.

Manufacturing companies have not been considered in this analysis because in the database [6] available on the Italian biotechnology industry there are no start-up firms that belong to this type of business model in Italy.

The four firms considered in this study successfully overcame the startup stage as the most used performance indexes [7, 8, 9] highlighted:

- Increase in R&D investments
- Increase in the number of employees
- Number of patents obtained
- Number of products/processes/services being developed.

At this point, it is interesting to identify the success factors that have allowed these firms to overcome the startup stage successfully; in this

way, a connection is made between success factors and business models.

The Success Factors of Biopharmaceutical Startup Firms

The resource-based view represents the theoretical framework that has been adopted in this study in order to identify success factors; particular attention was then given to the set of resources and competences developed by the firms. In particular, resources were defined as stocks of available factors that are owned or controlled by the firm [10], while competence was defined as “the collective knowledge of an organization”, and in particular, “the capacity for the team of resources to perform some tasks or activities” [11].

While analyzing competences, it emerged that their nature changed according to the type of business models adopted.

In case A, although technical-scientific know-how is very important for the development of new products, managerial competences also play a fundamental role in the success of the startup; indeed, the study identified the following as the most important managerial skills:

- Ability to choose profitable research projects
- Management of human resources
- Creation of an efficient collaboration network
- Ability to find financial resources.

While this study was being carried out, Firm B was in a similar situation to Firm A because it carried out research and clinical development, even though it had built the production plant and was setting up a sales network. In this case, technical know-how (mainly combinatorial chemistry and high throughput screening) and managerial competences are the most important success factors for firm B as well. Concerning managerial competences, the skills that emerged from the analysis are the following:

- Ability to absorb complementary knowledge from alliances
- Management of human resources
- Ability to manage post-approval activities
- Ability to find financial resources.

The literature [12, 13] sustains that production and marketing skills are fundamental for the success of integrated biopharmaceutical firms, but at this point these skills cannot be examined because of the young age of the companies.

Firm C focused on quality excellence as the fundamental guiding force behind all these activities. From the startup phase, the management's efforts were geared towards the implementation of a set of procedures and practices (e.g. the good manufacturing practices system) that ensure the manufacture of high quality products. The efforts of this firm's management were devoted to the creation of a culture of organization focused on quality excellence and many activities (weekly meetings, training programs, team building) were implemented for this purpose.

Firm D overcame the startup phase by developing a tight network of relationships with many different external partners, which allowed the firm to widen its range of services, increase its technical knowledge and strengthen its customer portfolio. The firm's management guided its activities to overcome its present confines in order to create a new organizational configuration: a network of firms, with units comprising different organizations, such as research institutes, customers, diagnostics laboratories, universities, etc. Even the attention given to customers emerged as a critical element for the success of the startup.

Finally, it is important to underline that all the firms considered were founded by people who had previously worked for multinational firms and thus had substantial technical and managerial experience in this industry. In all the firms analysed, many different organizational processes have been activated by the management in order to transfer their tacit knowledge to new company employees.

Lessons

This study on the one hand identifies a taxonomy of business models in the biopharmaceutical industry and on the other hand shows how four biotechnology startups overcame the startup stage successfully. As illustrated above, startup success factors encompass a diverse range of distinct competences according to the type of business models adopted. Table 1 shows the success factors associated with each business model:

In other words, this case analysis illustrates that the success elements are connected with the firm's strategic value chain activities.

In the case of new biotechnology firms, where research activities play a critical role in success, specific technical and scientific know-how (e.g. in target identification/validation, or in lead identification/optimization) is fundamental.

In the case of integrated firms, where different value chain activities can play a critical role in success, both technical and scientific know-how, as well as an ability to perform approval activities and production and marketing competences, are important.

In the case of services firms, where the most important activities are located at the end of the value chain, the ability both to satisfy customers and to establish many relationships with different organizations are strategic for success.

Finally in the case of firms that carry out industrial development and production for other firms, the ability to guarantee excellence in final-product quality is the most important element for the success of a firm.

Type of business models	Success factors
New biotechnology firm	Scientific and technical know-how Managerial competences
Integrated firm	Scientific and technical know-how Managerial competences (production and marketing skills are hypothesized)
Service firm	Network relationships Attention to customers
Biotech suppliers	Excellence in quality of products

Table 1: The success factors for each business model analyzed

It is interesting to point out that, as Table 2 shows managerial competences played a fundamental role in the success of all the startups examined regardless of the type of business models adopted; management of human resources, the ability to build and manage a network and implementation of the quality system are some examples of the managerial competences required. In all the cases analysed, these competences are generated by the founders who had accrued significant experience in this industry.

The results of the study confirm the recent literature on this topic. In fact many studies [14, 15, 8] have maintained the importance of inter-organizational relationships, e.g. networks that generate new knowledge and create competitive advantage. Even the role of technical competence in the success of biopharmaceutical firms has long been recognized by many Authors [12, 16, 13]; Pisano [17] in particular stressed the role of the production process to guarantee a quality product. If, on one hand, the role of technical competence

is fundamental, on the other hand managerial competence can also play a significant role in the success of biotechnology firms [18, 2].

The study is original in that it concerns the identification of different strategic competences according to the type of business model adopted.

The suggestion emerging from this study is very important in particular for academic startups, where managerial skills are usually lacking in the scientific staff working at the university; for this reason the assistance given by technology transfer offices or other local authorities, in terms of organizational and financial support, could be very important.

In particular in Italy, where there are very few university spin-offs in the field of biotechnology, an interesting solution to joint scientific and managerial competencies could be the launch of university startups where the founders are a team of both academic scientists and industry managers.

Type of business models	Managerial competences
New biotechnology firms	<ul style="list-style-type: none"> - ability to choose profitable research projects; - management of human resources; - creation of an efficient collaboration network; - ability to find financial resources.
Integrated firms	<ul style="list-style-type: none"> - ability to absorb complementary knowledge from alliances; - management of human resources; - ability to manage post-approval activities; - ability to find financial resources.
Service firms	<ul style="list-style-type: none"> - ability to manage a network of different relationships; - ability to satisfy customers.
Biotech suppliers	<ul style="list-style-type: none"> - creation of a culture of organization focused on quality excellence.

Table 2: The most important managerial competences for each of the business models analyzed

Finally, a look at the study conducted by Weisenfeld-Schenk [19], who proposed a typology of biotechnology firms based on the strategic types described by Miles & Snow, reveals some similarities and suggestions for further research. The Weisenfeld-Schenk study classifies biotechnology firms into three main groups: the first group is constituted by companies that “pursue process improvements and are lowest on new product development”; the second group encompasses companies that are mainly devoted to basic research instead of applications engineering; and the third group is the closest to

the market and between the first and second groups. Looking at this classification, we can see, for example, that cluster 2 described by Weisenfeld-Schenk seems to share some common points with the new biotechnology firms presented in our study. Further research could then investigate the strategic behaviour of biotechnology firms through a quantitative analysis that takes into consideration both the strategic types suggested by Weisenfeld-Schenk and our own findings about business models.

References

- [1] Orsenigo, L. (2001), The (failed) development of biotechnology cluster: the case of Lombardy, *Small Business Economics*, 17, 77-92.
- [2] Hall, L.A, Bagchi-Sen, S (2002), A study of R&D, innovation, and business performance in the Canadian biotechnology industry, *Technovation*, 22, 231-244.
- [3] Gambardella, A (1996), *Prospettive e proposte per uno sviluppo della R&S nell'industria operante in Italia nella biotecnologia farmaceutica*, Assobiotec Federchimica.
- [4] Chiaroni, D., Chiesa, V., Toletti, G. (2003), Business models in the bio-pharmaceutical industry, *The R&D management Conference*, Manchester, 7-9 July.
- [5] Bigliardi, B., Nosella, A., Verbano, C., (2005), Business models in Italian biotechnology industry: a quantitative analysis, *Technovation*, Volume 25, Issue 11, November, 1299-1306.
- [6] Nosella, A., Petroni, G., Verbano, C. (2004), Characteristics of the Italian Biotechnology Industry and new business models: the initial results of an Empirical Study", *Technovation*, vol.25, n.8, pp.841-855.
- [7] Zahra, S. A., George, G. (1999), Manufacturing strategy and new venture performance: a comparison of independent and corporate ventures in biotechnology industry, *Journal of high technology management research*, 10, 313-345.
- [8] Baum, J.A.C., Calabrese, T., Silverman, B.S. (2000), Don't go it alone: alliance network composition and startups' performance in Canadian biotechnology, *Strategic management journal*, 21, 267-294.
- [9] Garcia, C.Q., Velasco, C.A.B. (2002), Co-opetition and performance: evidence from European biotechnology industry, *II annual conference of Euram on innovative research in management*, Stockholm (Sweden), may 9-11.
- [10] Amit, R., Schoemaker, P.J.H. (1993), Strategic assets and organizational rent, *Strategic management journal*, 14, 33-46.
- [11] Grant, R.M. (1991), The resource based theory of competitive advantage: implications for strategy formulation, *California management review*, spring, 33.
- [12] Henderson, R., Cockburn, I. (1994), Measuring competence? Exploring firms effects in pharmaceutical research, *Strategic management journal*, 15, 63-84.
- [13] DeCarolis, D.M. (2003), Competences and imitability in the pharmaceutical industry; an analysis of their relationship with firm performance, *Journal of management*, 29, 27-50.
- [14] Powell, W.W. (1998), Learning from collaborations: knowledge and networks in the biotechnology and pharmaceutical industries, *California management review*, 40, 228-240.
- [15] Decarolis, D.M., Deeds, D., L. (1999), The impact of stocks and flows of organizational knowledge on firm performance: an empirical investigation of the biotechnology industry, *Strategic management journal*, 20, 953-968.
- [16] Quelin, B. (2000), Core competencies, R&D, management and partnership, *European management journal*, 5, 476-487.
- [17] Pisano, G.P. (1997), *The development factory: unlocking the potential of process innovation*, Harvard business school press, Boston, Massachusetts.
- [18] Woicheshyn, Hartell (1996), Strategies and performances of Canadian biotechnology firms: an empirical investigation, vol 16, n 5, pp 231-243.
- [19] Weisenfeld-Schenk, U. (1994), Technology strategies and the Miles & Snow typology: a study of the biotechnology industry, *R&D management*, 24, 57-64.

Research Paper

Detergent Phosphates: an EU Policy Assessment

Jonathan Köhler^{*#}

* Faculty of Economics, University of Cambridge, Sidgwick Avenue, Cambridge, CB3 9DE, UK

Correspondence to: j.koehler@econ.cam.ac.uk

Abstract: Sodium tripolyphosphate (STPP) is an important ingredient of many detergents. The use of STPP has been associated with the environmental problem of “eutrophication”, the increase of nutrient levels in water, which can lead to the formation of large masses of algae or blooms which are unsightly, cause slow moving water to be turbid, and may be toxic. This paper considers policies to reduce the use of STPP in detergents and assesses their success in reducing eutrophication together with the impact on the phosphate industry. The extent of eutrophication has been reduced, but there is still an ecological problem in many areas. Policy directed specifically at detergent phosphates has now been effectively made redundant by the EU requirement to install tertiary treatment plant. While the phosphate industry has experienced a considerable reduction in demand and has consequently contracted, it can be expected to stabilise. Policy on phosphorus will continue to evolve, from the current emphasis on implementing the EU Directive on Urban Waste Water Treatment to dealing with the consequences of this – sludge – and addressing the other main source of phosphorus – agriculture.

1. Introduction

Laundry detergents are an item that appears on everybody's shopping list; they perform one of the basic household functions. An important ingredient of many detergents is phosphate in the form of sodium tripolyphosphate (STPP). Its introduction in synthetic detergents in 1948 heralded a step increase in performance over the soap-based products that had been used before. Subsequently, the markets for synthetic detergents grew rapidly in Europe and the US and the production of STPP became a significant part of the phosphate industry, although it has always remained a relatively small part of the market in comparison to fertilisers, which account for around 85% of phosphate production.

However, there is an ecological problem. A consequence of the use of STPP in the domestic environment can be an increased level of phosphates in household waste water, which may then contribute to the phosphorus load in rivers, lakes and inshore waters. This can be an environmental issue because of "eutrophication", the increase of nutrient levels in water, which can lead to the formation of large masses of algae or blooms which are unsightly, cause slow moving water to be turbid, and may be toxic. The emergence of eutrophication as an issue after the introduction of STPP led to the identification of the use of STPP with this environmental problem, which resulted in both changes in consumer perceptions and the development of government and EU policy on phosphates. However, the presence of cyanobacterial blooms and turbidity is still an important environmental issue in many European countries, the USA and Japan [1].

This history provides an interesting case study of the development of environmental policy and its impact on consumers and industry. [2] and [3] discuss the environmental issues arising from the use of phosphates in detergents. There is, however, very little literature on the application of environmental policy to detergents. [4] is an assessment of taxing phosphates in detergents and [5] considers environmental policy on phosphorus, with application to phosphorus recycling. This paper explains why phosphates are used in detergents and considers policy on phosphates in

detergents in response to the ecological problem of eutrophication. We concentrate on the EU, using wider international comparisons when they are informative. The success of the policies in addressing eutrophication is assessed, together with the impacts on the detergents market and on the phosphate industry. This enables some conclusions to be drawn about the nature of environmental policy, applicable to other environmental policy issues.

The paper is structured as follows. Section 2 briefly explains why phosphates are used in detergents and looks at alternative chemicals that can be used. Section 3 describes the ecological problem of eutrophication and assesses the role of detergents as a contributor to the phosphorus load. The environmental solutions that are available are introduced. In order to adopt these solutions, government action is required and section 4 looks at the extensive policy response of individual countries and the EU. The success of these policies is assessed. Section 5 considers the impact of the environmental issue of eutrophication and the policy response on the detergent market. Section 6 draws some general conclusions on the nature of environmental policy. It assesses the effectiveness of the policy response and discusses ways in which environmental policy on detergents and phosphorus might effectively address the continuing issue of eutrophication in the future.

2. The use of phosphates in laundry detergents

The reason why STPP is used in detergents is that it performs several very useful functions. No other single chemical product has been found which performs the same combination of functions as a 'builder' – a chemical added to soap to improve the performance of the detergent formulation – and contributes so effectively to the performance of modern household detergents, where washing temperatures are low and soiling of the clothes is generally relatively light. STPP performs the following functions [6]:

1. As with all complex phosphates, STPP is alkaline, so it counteracts hardness in water. 'Hardness' means that the water contains salts

such as calcium chloride or magnesium chloride, which will leave crusty deposits on the clothes. Dirt and the textiles may also contain calcium and magnesium ions. STPP reacts with these salts to combine them into other phosphate containing compounds which do not precipitate, so avoiding further deposits of precipitated crystals on the clothes. This has the additional advantage of preventing deposition on the heating elements in the washing machine [7].

2. A combination of 50% detergent and 50% STPP provides a more effective washing performance than using 100% detergent, other factors being equal. Condensed phosphates increase the surface activity of the active washing compounds [8]. An additional effect is that the alkaline STPP raises the pH value in the wash liquid (i.e. acts as a chemical buffer), which means that the ions in the dirt and textile fibres become more strongly charged. This in turn leads to increased repulsion between the ions in the dirt and in the textile, thus increasing washing performance. Of all the phosphate compounds, STPP has the greatest synergy in these respects.
3. Complex phosphates such as STPP 'deflocculate', which means that they break up large particles of e.g. mud or clay into smaller ones. Furthermore, they keep fine particles in suspension in the washing water and prevent them recombining, thus avoiding redeposition on the clothes. Related to this property of deflocculation, they emulsify oily materials, that is they also break up oily masses into smaller particles.
4. Because of the alkalinity of STPP, it will redissolve Calcium and Magnesium compounds that are present from detergent in previous washes and will reactivate any remaining soap. Therefore, the performance of the detergent is enhanced in this case.

This combination of functions means that phosphates and STPP in particular can play a very important role in the washing process. If phosphates are not used, they must be replaced with some material or combination of materials that performs a similar combination of functions, if the performance of the detergent is to be

maintained. In recent years, there has been innovation in new products such as 'compact' powders and tablets. These help to prevent the excessive use of detergents. STPP is particularly suitable for use in both of these new types of product.

2.1 Alternatives to Phosphates in Detergents

As will be shown in sections 3 and 4 below, concern about the environmental impact of phosphates in synthetic detergents resulted in the introduction of various controls and restrictions on the use of phosphates in household detergents. This led to a search for alternative builders. Several replacements have been tried:

Sodium citrate

Sodium citrate was utilised as a builder, but it has some disadvantages [9]. It is considerably more expensive than STPP (twice as much at that time) and does not perform as well in removing calcium and magnesium ions. This lower performance is least marked at very low temperatures.

Ethylene diamine tetraacetic acid (EDTA) and nitrilotriacetic acid (NTA)

Both of these chemicals are effective at abstracting calcium and magnesium ions and NTA in particular can largely replace STPP as a builder [10]. However, it does not buffer as strongly as STPP and is less effective as a particle disperser. The main problems with NTA are that there has been some evidence that it is carcinogenic and its great strength in combining with metal ions has caused fears that heavy metals in sewage sludge may be taken up and hence mobilised [10]. This could then result in peak concentrations of heavy metals in rivers and lakes being above regulated level. [11] argue that this latter risk is not significant, but these environmental concerns have resulted in both EDTA and NTA being excluded from EU

Ecolabelable automatic dishwasher and domestic laundry detergents.

Zeolite A - polycarboxylate

The most successful alternative has been Zeolite A, a relatively inert substance derived from aluminium oxide [12]. It has a reasonable performance in abstracting calcium and magnesium ions but is limited as a builder. It does not buffer during the washing process and does not prevent redeposition of soil particles in the wash liquid, so it has to be used with a cobuilder, usually polycarboxylic acids (PCAs). These are oil-based compounds that soften water and keep soil particles in suspension. Zeolite-PCA builders are now used in almost all countries where STPP is no longer used, in particular the USA, Germany and Italy. It is also extensively used in liquid detergents. Its real advantage is that it never been perceived as presenting a serious environmental problem, while providing reasonable performance for modern household detergent powders although concern has been expressed over the impact of PCAs on heavy metals in water sources [13]. It also results in increased volumes of sludge from sewage treatment plants in comparison to STPP. Zeolites and PCAs contribute significantly to volumes of sludge produced by sewage works, probably generating significantly more sludge than detergent phosphates in cases where either sewage phosphorus removal is not necessary, where phosphorus removal is carried out essentially by biological processes or if phosphorus recycling is installed. The inclusion of zeolites in detergents is estimated to increase sewage works sludge production by 15% [14].

Comprehensive life-cycle comparisons of STPP and Zeolite A – PCA have been undertaken for European conditions [12,15]. These found that the overall environmental impact of the two builder systems was roughly equal in both the UK, which has relatively simple waste water treatment and in Scandinavian countries which have very advanced waste water systems. [15] concludes that using STPP exclusively as a builder is the

option with the lowest environmental impact in terms of waste water treatment only. This is mainly because Zeolite builders result in a greater volume of sludge from sewage treatment works and because zeolites and PCAs have no recycling value, whereas phosphorus can be usefully recovered and recycled. Although Life Cycle Analysis methodology has evolved since these studies, more recent work [16] has confirmed the coherence of these studies' data and conclusions.

In summary, STPP considerably improves performance of detergents. STPP is particularly useful for heavy soiled washes, and is extensively used in industrial laundry detergents as well as in dishwasher detergents, even in countries where it is no longer present in household detergents. There has subsequently been extensive research into alternatives to phosphates and STPP in particular as a builder. There are alternatives of which Zeolite A is the most successful, although it increases sludge volumes in waste water treatment.

3. Eutrophication and Detergent Phosphates

3.1 Eutrophication

The environmental issue associated with phosphates is eutrophication and the subsequent growth of blooms of cyanobacteria and microscopic algae. Eutrophication describes a situation in which a body of water receives an increased supply of plant nutrients which provide the conditions for the rapid growth of these blooms. Both phosphorus and nitrogen are essential chemicals for plant growth, but are only required in very small quantities under 'natural' conditions. Therefore, if the supply of either of these nutrients is suddenly increased, the conditions for plant growth will change and the ecosystem will adapt. In particular, given suitable environmental conditions, blooms will form. [17] and [18] provide empirical evidence that phosphorus can be the limiting nutrient

determining the extent of blooms. The growth of algae and cyanobacteria also depend on the water temperature and the availability of sunlight for photosynthesis. Warm water temperatures and plenty of sunlight may combine with slow flowing or stationary water to give the conditions under which blooms can grow.

It is important to note that the size of blooms is governed by these different limiting factors. If the water is warm, there is plenty of sunlight and the requisite minerals, but initially a low level of phosphate, then the introduction of phosphate will cause a growth of the blooms. However, if there is already plenty of phosphate and the growth is limited by, say, nitrogen, then the addition of phosphate will not cause any growth. The relationship between biomass and phosphorus has been statistically estimated in the 'Vollenweider model', but because of the other potentially limiting factors, there is no continuous function between biomass and the quantity of phosphate [19]. [20] report that while blooms are associated with eutrophication, there is generally a low correlation between cyanobacterial biomass and total phosphorus or total nitrogen. [21] consider that biological productivity cannot be accurately predicted by simple phosphorus load approaches.

Algae and cyanobacterial blooms are a problem for the environment. The growth of large masses of these blooms may lead to the deoxygenation of deeper waters, threatening rare fish species and invertebrates. Reeds and other submerged plants may be lost and there can be indirect effects on herbivorous bird species. There is thus a loss of the variety of habitat and hence diversity of species [22]. The blooms may also block water filtration systems. Cyanobacterial blooms in particular may have an offensive odour and colour, forming noxious scums and may be toxic [23]. [24] report an incident at Rutland Water, UK in 1989 in which a total of 15 dogs and 20 sheep died after drinking contaminated water. [25] report an incident at Rudyard lake, Staffs., UK where a group of soldiers suffered from gastro-intestinal ailments, one from hallucinations and another from atypical pneumonia. In 1989, 169 water bodies in England and Wales were considered to have problems with cyanobacteria and 68% of 78 sites tested were found to have cyanobacterial toxins [26].

However, [22] consider that in the UK, the growth of cyanobacterial blooms is localised, rather than a widespread problem. They also report that the incidence of environmental problems due to eutrophication in the UK was at a similar level in the 1980s compared with the 1970s. Up to 1989, 16 European countries had reported blooms [27] and blooms have been reported in Australia, Canada, Japan, South Africa and the USA [23]. [28] summarised the situation in Europe at the beginning of the 1990s in table 1:

A recent international survey [1] surveys the wider international context and concludes that phosphorus pollution remains a significant issue in both developing countries and the EU, US and Japan.

3.2 The contribution of detergent phosphates to phosphate loading

Detergent phosphates are a significant, but secondary, source of phosphates in rivers and lakes. Humans and animals are by far the most important sources. [28] state that of phosphorus input to the aquatic environment in the EU, the most important contributors are livestock waste (34%), human waste (24%) and agricultural fertilisers (16%). Detergent phosphates form 10%. [29] state that for waste water input to sewage plants, the most important source is human waste, detergents form between 9% and 50% and that manufacturers' estimates were 40%; a current manufacturers' estimate is 20-25%; and industrial processes contribute 9% in the UK. [30] states that detergents led to 40% of water 'over-fertilisation' in Austria. Between 30% and 90% of phosphorus loading in rivers is from non-point sources i.e. agriculture [31] and this range is confirmed by [32] who state that in the Minnesota River, US, non-point sources contribute 35% of phosphate loading with low rainfall up to 90% loading in high rainfall. There are some surface waters in which the phosphorus load is dominated by point sources. In 1989 the river Po, Italy, received 67% of phosphorus from point sources and 29% from agriculture; the German Rhine received 77% from point sources and 23% from agriculture in 1985. For 1989-1992 in all of (West) Germany, 52%

Country	Extent	Key areas affected
Belgium	High	Most inland waters
Denmark	High	Most inland waters, North Sea, Kattegat, Baltic
France	Low	Loire, Meuse, Saone and possibly other rivers
Germany	High	Many inland waters, Bavaria, Rhine, North Sea, Baltic
Greece	Medium	Potential threat to limited inland and coastal waters
Ireland	Medium	Potential threat to inland waters
Italy	High	Most lakes and reservoirs, Rivers Arno, Tevere, Po, Adriatic
Luxembourg	Medium	
Netherlands	High	All inland waters
Spain	Medium	Many inland waters
Portugal	Low	
UK	Low	Lough Neagh, Anglia, some other local areas
Switzerland	High	Many lowland lakes

Table 1: Extent of waters affected by eutrophication; Source: [28]

came through point sources and 42% from agriculture [33].

The conclusion to be drawn from this evidence is that detergent phosphates may indeed lead to eutrophication and the consequent health hazards and degradation of ecosystems. However, the conditions under which these problems arise are limited and inherently site specific. The contribution of household detergents to the total phosphate load that finds its way into rivers, lakes and reservoirs varies considerably. Where phosphorus loading is dominated by waste water inputs, phosphorus from detergents might contribute up to 25% or so of the phosphorus loading. It is not possible to determine in general whether the removal of a certain amount of phosphate will reduce the incidence of blooms or whether an increase in phosphorus loading will cause blooms to develop or grow.

3.3 Solutions to eutrophication involving phosphorus – and their difficulties

Where eutrophication has been caused by phosphorus loading, it can be removed by reducing the phosphorus load, although ecosystems can show considerable hysteresis in their response if the algal blooms have killed off the original species. Although the largest source is agriculture, since phosphate removal from diffuse sources is impracticable, the approach to controlling these sources has to be one of managing the initial use of fertilisers and the careful use and/or disposal of manure [34]. Given this difficulty, there were two relatively obvious courses of action: the restriction of phosphates in household detergents and the treatment of waste water in sewage plants to remove phosphorus. The adoption of alternatives to the use of STPP in detergents has happened to a considerable extent in the EU, as is discussed below. The other

obvious possibility is to treat waste water at sewage plants to reduce the phosphorus content of discharges. Treatment of urban waste water to remove phosphorus has a greater potential to change the output into rivers and lakes, because it works on all the phosphate content of waste water instead of only the small fraction from detergents. Also, phosphate removal in sewage works is generally installed at the same time as nitrogen removal, thus also reducing the input of this nutrient to surface waters. Phosphorus technologies are extensively covered in [35]. The technology exists to remove 95% or more of phosphorus from waste water, if the most comprehensive (tertiary) treatment systems are fitted [36].

However, phosphorus removal using the current commercial processes results in the production of phosphorus rich sludge, which must then be disposed of. [35] reviews the state of the art in recycling technologies. Recycling by spreading sludge as fertiliser is the most effective environmental option in many cases [37]. However, in some regions where there is a high population density and limited agricultural land, there may be more sludge produced with high levels of removal than is required for agriculture. Sludge is bulky and therefore has high transport costs, so there must be a demand close to the sewage treatment plant if the economic cost is not to be high. While this is in general the case in the UK, it is not so in many parts of Europe and the US [38]. Most sludge will be produced in urban areas and would have to be distributed to the agricultural areas. This has been found to be the case in the Netherlands and in a study in the Lothian region of Scotland [39]. There are also serious concerns about the concentrations of heavy metals in sludge from waste water, which would also be of concern if their use in fertilisers increased the metal concentration in the food chain, to the extent that the European commission has proposed much stricter controls on the composition of sludge used for spreading [40].

An alternative is to extract the phosphorus from the waste water stream in such a form that it can be reused, either in agriculture as a fertiliser or by phosphate manufacturers as a substitute for the raw material, phosphate rock. A further possibility is to dry and incinerate the sludge, but this requires

careful control over the combustion products containing heavy metals, mercury, dioxins and furans, acid gases, as well as NO_x and N₂O [41]. Another possible use is to dry the sludge and use it for construction materials. In Tokyo, it is used for pavement construction [4].

4. Policies on detergent phosphates, their success and impacts on the phosphate industry

The potential factors causing eutrophication – i.e. increased input of nitrogen and phosphates into watercourses, lakes and seas – were rapidly identified. The increase in phosphorus input due to the introduction of synthetic detergents was perceived to be a major contributor to eutrophication and led to the development of policy to control phosphorus discharges. There is a large literature on environmental policy; initially governments concentrated on limiting pollution by imposing regulations or standards on firms, but the emphasis has moved towards policies employing economic incentives, in particular environmental taxation. [42] surveys the EU experience. Policies on phosphorus have followed this pattern, starting by setting national standards through regulation, through international agreements where necessary. Most policy on phosphates has been of this nature. Germany and the Netherlands are among the signatories to the Rhine Action programme, which required a 50% reduction in inputs of phosphorus and nitrogen to surface waters [43]. With the more recent trend towards the use of economic instruments, such as taxes and charges, the taxation of phosphates is now being considered and has been enacted for detergents in France in particular. There have also been many voluntary agreements to reduce phosphate use in detergents and these have led to significant reductions in phosphate use.

4.1 Command and Control instruments and voluntary agreements between governments and industry to restrict detergent phosphate

Phosphate levels in detergents and also in fertiliser input to agriculture can be specified by

legislation or administrative instruments. Given that the main contributor is human waste, which as a biological function cannot be reduced, controlling phosphates in detergents offered the best way of reducing phosphate input into urban waste water. The response of individual countries has depended on the severity of eutrophication and its geographical extent. In 1985, Italy introduced a restriction of 4% STPP content in household detergents (a low enough proportion to prevent effective use of STPP) in negotiation with industry. This was followed by regulatory bans on phosphates in household detergents in Switzerland and Norway and subsequently Austria in 1994. Many US states introduced bans in the early 1990s and Japan also discontinued the use of STPP in detergents. In some countries such as Germany and Italy, and more recently Ireland, a voluntary agreement to reduce STPP use is in effect equivalent to a “ban” of phosphates in household laundry detergents. In most other European countries, and in some EU Accession countries, voluntary agreements are in place limiting detergent phosphate levels to the minimum necessary for phosphates to play an effective role in the detergent.

However, since cyanobacterial blooms and algae are still a widespread problem in Italian surface and coastal waters, regulating detergents in this way is not always effective. [28] found that there were no examples of phosphate limits in detergents making any large impact on eutrophication and [44] concluded that moving to phosphate free detergents would not measurably change phosphorus inputs from the river Redon into Lake Geneva.

4.2 Ecotaxation of detergent phosphates

The modern trend in environmental policy has been to move towards the use of ‘economic instruments’: taxes/subsidies and tradeable permit systems. These types of measures have long been proposed by economists, because under suitable conditions they offer the possibility of taking the costs of pollution abatement into account as well as the pollution reduction and therefore being economically efficient. The idea is that if there are external costs of e.g. pollution to society imposed

by some activity, such as the use of detergents, then the user of the detergent should face costs that reflect the external costs. Taxes are usually most appropriate where there is a tax collection system already in place. The advantage is that the tax provides an economic incentive for polluters to change their behaviour and each individual polluter can choose their level of abatement and hence the amount of tax they pay. Thus it is easy to take account of differences in abatement costs between different polluters. In the context of eutrophication, a national tax has the disadvantage that it does not allow for the difference in requirements for the reduction of phosphates between water basins, so the effects may be insignificant or inappropriate in some areas. The only example of a tax on detergents is the French TGAP, discussed below. Taxation of other polluting activities is much more common, both in Europe and in other OECD countries; [42] surveys European environmental taxes. Belgium and the Netherlands have introduced surplus manure charges, which are based on the emissions of phosphorus and/or nitrogen in excess of the environmentally acceptable manure loads per hectare. Norway, Sweden and the USA have introduced fertiliser charges which are taxes on products rather than taxes directly related to the pollution caused.

The fundamental principle of ecotax design is that it should provide an incentive for the polluter to change their behaviour in a way that reduces the undesirable or polluting activity, in this case eutrophication. [45] considers environmental tax design. Usually, a more effective tax requires more measurement or more complex charging schedules. Another factor is the use of the revenues generated by a tax. The revenues may be designated for use in the same area from which the tax is raised (known as earmarking) e.g. paying for the installation of water treatment or they may be used to reduce other taxes such as employment taxes to improve the overall efficiency of the taxation system. [45] argues that the earmarking of tax revenues does not have an economic justification, but is used to make the introduction of a tax more acceptable.

In the case of detergents, the use of a national tax on detergents containing phosphates is problematic for several reasons. In many areas, the

main phosphate loading will come from agricultural sources, so a detergent tax does not address the problem. Even if the main phosphorus load comes from urban waste water, since detergents contribute a small proportion of phosphates, a reduction in detergent use will not prevent eutrophication in most cases. It should also be noted that demand for detergents is relatively inelastic; consumers will always wish to wash clothes and will not be very sensitive to changes in detergent prices. Household expenditure on detergents is also a small proportion of expenditure: [46, 47] shows that expenditure on all cleaning and maintenance products is between 0.5% and 1.5% on average in most EU countries, so even a considerable increase in price of detergents is unlikely to cause consumers to use much less. Therefore, an extremely high rate of tax on phosphate detergents would be necessary to have any significant impact on the incidence of cyanobacterial blooms and algae.

The French TGAP

The one example of a tax specifically on phosphates in household detergents is the French 'Taxe Générale sur les Activités Polluantes (TGAP)', which came into force in January 2000. The TGAP contains several different taxes on various activities which are seen as polluting. These include: activities modifying water movement and flow, gravel extraction, industrial outputs of heated water and radioactivity, pesticides (but not fertilisers) and laundry detergents. The stated objective of the TGAP is to reduce polluting activities through an improved application of the polluter pays principle and the raising of revenues to finance the 35 hour week and hence employment [48]. The part of the tax applied to detergents is levied on the sales price to the consumer as follows [49]:

Detergents with:

less than 5% STPP	470 FF/tonne
5-30% STPP	520 FF/tonne
more than 30% STPP	570 FF/tonne

This represents 2.35-2.85 FF for a 1 kilo standard detergent packet, which is approximately between 2-3% of the sale price for concentrated powders and 10% for the cheaper powders. The expected revenue for the first year is 500 million FF, out of a total of 4 billion FF for the TGAP. Applying the criteria for efficient taxes outlined above, it can be seen that the TGAP detergent tax does apply directly to the issue of concern i.e. the presence of detergents in urban waste water. The collection of the tax will be relatively simple, because the systems in place for VAT on consumer products can be used. The variation in rates of 0.5 FF or between 0.4% and 2% per packet is probably so small that any consequent reduction in sales is not detectable. These price variations are certainly much smaller than price differences between different products and promotions etc. However, it will probably not achieve its environmental aims of reducing cyanobacterial blooms and algae in surface waters. As discussed above, STPP is a small part of the phosphate load and so this marginal additional load will only be significant in a small number of cases. As the change in detergent use due to this tax will be small, the change in STPP input into urban waste water will also be small. Detergent STPP forms 9-50% of the phosphate input to waste water and a maximum 25% of the input to rivers, lakes and reservoirs. Assuming the maximum of the range, 50%, if there is a 5% reduction in detergent use, then there would be a 2.5% reduction in STPP input into waste water and a 1.25% reduction in phosphate input to surface waters as a maximum where phosphate loading was dominated by urban waste water. Even for waters sensitive to the phosphate load, this is very unlikely to have any great effect on the growth of cyanobacterial blooms.

4.3 Waste water treatment

Denmark, Germany, the Netherlands, Switzerland and Sweden have all installed a large number of phosphate removal systems. A far-reaching step was taken by the EU in 1991 with adoption of the Directive on Urban Waste Water Treatment (Directive 91/271/EEC), which required installation of phosphorus removal at waste water treatment plants such as to remove

most of the phosphorus [5]. This is resulting in the widespread installation of tertiary treatment plant. The new Water Framework Directive [50] maintains the requirements of existing Directives (e.g.91/271) as the minimum baseline to be developed at the catchment level. Since the growth of cyanobacterial blooms and algae is very dependent on the local conditions, a more integrated approach to nutrient load at a local level offers the possibility of more efficient and effective action.

The implementation of this directive, which came into force in 1991 with the requirements regarding phosphate removal applicable by 31/12/1998, is assessed in [36]. Progress has been variable in the different member states, both in the designation of sensitive areas that require phosphate removal and in the installation of treatment systems. While some processes could produce revenue from selling nutrient rich sludge for use as fertiliser or by recycling to phosphorus to phosphate manufacturers, this is not currently profitable [3]. Therefore, the finance must be raised either from public sources or through water charges. This will explain the delay in implementing the EU directive in some cases. However, the costs have not prevented countries such as Germany and Switzerland from installing many phosphate removal plants, so the costs are probably not a major barrier where eutrophication is perceived to be a serious problem.

4.4 Current incidence of eutrophication

While phosphate discharges have been reduced, phosphate concentrations are far above their natural levels in many areas in Europe and eutrophication continues to be an environmental issue. The most recent available evidence demonstrates that eutrophication is still a problem in many parts of the EU, in spite of a considerable history of policy measures over the last 25 years. [51] found that only 10% of 1000 river measurement sites across Europe had phosphorus concentrations below 50 $\mu\text{g}/\text{l}$ (the natural background maximum). It has been found that the cyanobacterial blooms may be extremely stable, especially in shallow waters, so that reduction of phosphorus input alone will not restore the waters

[52]. There have been some successes. For example in Lake Veluwe, the Netherlands, the installation of phosphate removal in the sewage works discharging into the lake in 1979 and additional flushing in 1985 enabled the lake to recover by the early 1990s, 10 years after the reduction in nutrient loading [53]. The Swiss policy of waste water treatment has also had some success in reducing the incidence of cyanobacterial blooms and algae, in particular in Lakes Geneva and Neuchatel [54]. [51] shows that mean phosphorus concentrations in European rivers generally decreased between 1987-91 and 1992-96 in Western Europe and in some countries of Eastern Europe. However, there are still many sites with very high phosphate concentrations. [51] also states that reductions in phosphorus loading from sewage works now need to be followed by reductions in loading from agriculture, as this is now relatively more important.

Although full compliance with the EU directive still requires far more extensive phosphate removal, [55] considers that the number of heavily polluted rivers in Western Europe has fallen from 25% in 1975-80 to approximately 5% in 1992-98, especially because of the installation of waste water treatment following the Urban Waste Water Directive. This will have been very effective where there was a high proportion of the phosphorus load from point sources, as in the river Rhine.

If countries such as Italy (where waste water treatment is relatively limited and there are serious problems with cyanobacterial blooms and algae) move towards compliance with the Directive by installing more treatment plants, eutrophication due to phosphorus should decrease and this might have a considerable effect on the overall incidence of eutrophication. Sweden, Switzerland and the Great Lakes region of the USA, for example, have implemented phosphate removal programmes, which have controlled the extent of eutrophication [15]. In Sweden it has therefore not been considered necessary to put any controls on phosphates in detergents. EU policy is now changing towards a water catchment based and hence localised approach, within the context of national and EU policy.

5. Market impacts

The understanding of eutrophication and subsequent policy has had a considerable impact on the market for detergents and detergent phosphates. We consider here evidence on consumer reactions and then look at the consequences for firms in the detergent market, from the viewpoint of the phosphate industry.

5.1 Consumer reactions and trends in phosphate use

Laundry detergents are an essential consumption item that is used very regularly and purchased frequently. The emergence of eutrophication as an environmental issue together with increased consumer awareness of environmental issues increased the perception of phosphates in detergents as environmentally damaging resulted in the policies described above. The consumer choice literature on detergents reflects this situation, in which phosphates are mentioned as an environmental issue [4]. In Denmark, Germany and the Netherlands, the market for detergents containing STPP disappeared, while in countries such as France and the UK, there is also a widespread opinion that phosphates are bad for the environment [4]. Since the detergent market is very competitive and marketing oriented, the consequence of this has been that detergent manufacturers have reduced the use of STPP in detergents. In France, detergents contained 24% STPP on average in 1985 which was reduced to 10% in 1998 [4]. 'Eco-friendly' detergent brands were introduced in response to this perception, but this was a temporary phenomenon, as the major manufacturers changed their main products to use less STPP anyway [56]. In Europe, the USA and Japan, the use of STPP in detergents has either been stopped or has fallen very considerably and is continuing to be reduced. In other countries such as Russia, China and Latin America, where there are also potentially large consumer markets, the use of detergents is increasing generally and there is little tendency to try and minimise the use of STPP [56,57].

5.2 Implications for the detergent phosphate industry

Position in the supply chain and detergent market conditions

Phosphates are an intermediate product in the detergent supply chain. The production of STPP is based on phosphorus rock as the raw material from which phosphoric acid is manufactured (although, as mentioned above, the technology also exists to recycle phosphates). STPP is sold to detergent manufacturers and detergents are sold through retail outlets, mainly grocery stores/supermarkets. The consumer detergent market is very concentrated, both in retail and in supply. In 1998, Proctor & Gamble and Unilever, the two largest firms in the market, had over 75% of the UK powder detergent market [57]. The retail market is large; expenditure on fabric cleaning products in the UK was £1.18 billion in 1998 with a further £98 million on machine dishwashing products [57]. It is mature; overall demand is roughly constant, although there has been a slow long term decline in volumes in Europe. This is due to fewer people being employed in manual labour and improved performance of detergents. Required quantities have decreased from 200g detergent/wash to 70-80g/wash, with lower washing temperatures, shorter wash cycles and a lower water use. Therefore, competition is intense with the manufacturers spending heavily on advertising (£76.8 million for fabric detergents in 1998, [57]) and innovation in new products such as 'compact' powders and tablets. The lifetime of a detergent formulation is only of the order of one year [4]. STPP is particularly suitable for use in both of these new types of product, so some increase in the use of STPP as these product types develop can be expected. The market for dishwasher detergents, in which STPP is usually used as the builder, is expanding but was only 22% of the laundry detergent market in 1998 [57].

Structure of the detergent phosphate industry

The STPP industry is also heavily internationally concentrated, with the main manufacturers being part of international industrial chemical companies [48]. There is also overcapacity in the European phosphate industry. After STPP was introduced by Procter and Gamble in 1948, the market and production increased rapidly until most countries had at least one manufacturer. The issue of eutrophication and the subsequent bans and restrictions then caused a rapid decline in the industry, with many plants being closed up to 1992 [4]. This led to consolidation of the industry into five producers in Europe. Two of the largest companies have recently been combined; Rhodia took over Albright and Wilson plc. and now has roughly 50% of the European manufacturing capacity [4]. The concentration has been associated with cutbacks in capacity, the latest of which is that Rhodia UK recently announced the closure of 2 of the 3 UK STPP plants with 300 redundancies. The reduction of 140,000T of effective capacity will mean that plants in Europe will improve from operating at 50-55% capacity to over 80% capacity [58]. [48] estimates the turnover of the sole STPP plant in France at 350Mn FF/year, with 150 employees [4].

Internationally, there are detergent markets which might expand. China is the best example, but there is plenty of recently installed manufacturing capacity. There is a relatively low level of detergent consumption in Russia and Eastern Europe and little use of zeolites as a builder so there is potential for growth there [4]. Latin America and South East Asia are also potential markets, although as STPP and powder detergents are quite difficult to transport, it is more probable that local manufacturing plants will be constructed.

Overall, the issue of eutrophication caused a decline in demand for detergent phosphates, resulting in a contraction of the industry and considerably reduced production volumes. There are no large new potential markets outside the EU, although new products such as compact powders and dishwasher detergents may stabilise demand for detergent phosphates.

6. Has policy on detergents been effective and what can future policy on phosphorus achieve?

As the discussion in section 4 above shows, policy to control phosphorus has reduced the extent of eutrophication, but there is still an ecological problem in many areas. Policy directed specifically at detergent phosphates has now been effectively made redundant by the EU requirement to install tertiary treatment plant, which removes most of the phosphorus in urban waste water, of which only a small proportion now comes from detergents. So, while policies on detergents may have reduced the environmental impact of detergents in some cases of eutrophication in the past, this would only be the case in a few particular situations in the future. The impact on the detergent market overall has been small, but in terms of phosphates in detergents, policy and market pressures have acted to considerably reduce the use of STPP. This has led to overcapacity in STPP production, with resultant consolidation of the phosphate industry. Because the industry is highly concentrated, there were considerable economic impacts where plants have been closed, but these are relatively few in number. New products and a move to waste water treatment as the main policy to control phosphorus loading should mean that the industry stabilises.

This case study of the history of environmental policy demonstrates three points. Firstly, sources of pollution from industry or consumer products are easily identified and are relatively easy for policy to influence. However, what is thought of as the main cause of deterioration in an ecosystem is often only the main cause in some instances. Secondly, because ecosystems have non-linear responses to changes in inputs, removing the last source of pollution that 'tipped the ecosystem over the edge' will often not return the ecosystem to its previous state, more drastic action may be necessary. Thirdly, the most effective policy may change over time. In the case of detergents, restrictions on phosphates in detergents have been effectively replaced by a requirement to remove phosphorus from urban waste water streams. This

will, in turn, lead to changed policy requirements in the future.

In particular, the sludge produced by waste water treatment will have to be dealt with and phosphorus loading from agriculture will become a more serious issue as the main remaining source of phosphorus. [35] surveys phosphorus recycling and [5] looks at policy for recycling phosphorus. This will be costly and require the development of new markets in sludge collection, transport and spreading or treatment. Since phosphorus in urban waste water is now being reduced, future policy will have to address the role of agriculture in contributing to phosphorus load into rivers, lakes and inshore waters. Because agriculture is a diffuse source of phosphorus compared to waste water outlets, its control is more difficult. Policy can provide incentives by taxing excess fertiliser and manure use, as in Belgium and the Netherlands [42]. A further possibility would be to recycle phosphate from animal manure, which could become economically attractive in areas of intensive livestock production [38]. There is a potential synergy with waste water treatment here: if a market for recycled phosphorus from waste water treatment plants is developed, it would be much easier for farms to locate a demand for their recycled phosphorus. [34] also make the point that since the main cause of high phosphorus loading problem is intensive livestock farming, policies to encourage mixed farming will also reduce the incidence of eutrophication.

To summarise, environmental policy is demonstrating some success in reducing the incidence of eutrophication. Full implementation of current EU policy can be expected to reduce eutrophication further. While the phosphate industry has experienced a considerable reduction in demand due to the recognition of the problem and has consequently contracted, it can be expected to stabilise. Policy on phosphorus will continue to evolve, from the current emphasis on implementing the Directive on Urban Waste Water Treatment to dealing with the consequences of this – sludge – and addressing the other main source of phosphorus – agriculture.

Acknowledgement

This paper is based on work undertaken for the Centre Européen d'Etudes des Polyphosphates – a European Chemical Industry Council (CEFIC) sector group. The author wishes to thank two anonymous reviewers for their comments on a previous draft.

References

- [1] Farmer, A. (2004), Phosphate Pollution: a Global Overview of the Problem in: E. Valsami-Jones (ed.). *Phosphorus in Environmental technologies: Principles and Applications*. London: IWA.
- [2] Kolber, E. (1990), Detergents, the Consumer and the Environment. *Chemistry & Industry*, No.6, 179-181.
- [3] Driver, J., Lijmbach, D. and Steen, I. (1999), Why recover phosphorus for recycling, and how?. *Environmental Technology*, 20(7), 651-662.
- [4] Köhler, J. (2001), *Detergent phosphates and detergent ecotaxes : a policy assessment*, a report prepared for the Centre Européen d'Etudes des Polyphosphates – a European Chemical Industry Council (CEFIC) sector group.
- [5] Köhler, J. (2004), Phosphate recycling: Regulation and Economic Analysis in: E. Valsami-Jones (ed.). *Phosphorus in Environmental technologies: Principles and Applications*, London: IWA.
- [6] Davidsohn, A. and Milwidsky, B.M. (1978), *Synthetic detergents* 6th ed. London: Godwin; New York: Wiley.
- [7] Merkenich, K. and Gohla, W. (1979), *Seifen Öle Fette Wachse*, 105, p.39.
- [8] Ullman (1999), *Ullman's Encyclopedia of Industrial Chemistry* 6th Edition. Wiley-VCH, Weinheim.
- [9] Stinson, S.C. (1987), Consumer Preferences spur innovation in Detergents. *Chemical and Engineering News*, Jan 26, 24-46.
- [10] Perry, R., Kirk, P.W.W., Stephenson T. and Lester, J.N. (1984), Environmental Aspects of the use of NTA as a Detergent Builder. *Water Research* 18(3), 255-276.

- [11] Brouwer, N.M. and Terpstra, P.M.J. (1995), Ecological and Toxicological Properties of Nitrilotriacetic Acid (NTA) as a Detergent Builder. *Tenside Surfactants Detergents*, May-Jun, 225-8.
- [12] Landbank (1994), *The Phosphate Report*. Landbank Environmental Research and Consulting, London.
- [13] CES (Consultants in Environmental Sciences Ltd.) (1991), *Pollutants in Cleaning agents: Final report*. Department of the Environment, March 1991, London.
- [14] French Regional Water Agency (FRWA) (1996), *Note Technique n°2 – SDAGE Rhône-Méditerranée-Corse, 12/1996*. French regional water agency, Paris.
- [15] Landbank (1995), *The Swedish Phosphate Report*. Landbank Environmental Research and Consulting, London.
- [16] EMPA (1999), *Life cycle inventories for the production of detergent ingredients*. EMPA report No. 244, EMPA, St. Gallen.
- [17] Jones, S.H. and Alexander, M. (1989), Phosphorus enhancement of mineralisation of low concentrations of 4-nitrophenol by *Flavobacterium* sp. in lake water. *FEMS Microbiology Letters*, 52, 121-36.
- [18] Haas, C.N., Bitter, P. and Schoff, P. (1988), Determination of the limiting nutrients for indigenous bacteria in Chicago intake water. *Water, Air and Soil Pollution*, 37, 65-72.
- [19] Reynolds (1992), Eutrophication and the management of plankton algae: what Vollenweider couldn't tell us. In: D.W.Sutcliffe and J.G.Jones (eds.) *Eutrophication: research and applications to water supply*, 4-29.
- [20] Canfield, Jr. J.E., Philip, S.E. and Duarte, C.M. (1989), Factors influencing the abundance of blue-green algae in Florida lakes. *Canadian Journal of Fisheries and Aquatic Science*, 46 1232-7.
- [21] Göde, H. and Gries, T. (1998), Phosphorus fluxes in Lake Constance. *Archives of Hydrobiology: special issues advanced limnology*, 53, 505-544.
- [22] Lund, J. W. G. and Moss, B. (1990), *Eutrophication in the United Kingdom: trends in the 1980s*. Report for the Soap and Detergent Industry Association, London.
- [23] Howard, A. (1994), Problem Cyanobacterial Blooms - Explanation and Simulation Modeling. *Transactions of the Institute of British Geographers*, Vol.19, No.2, 213-224.
- [24] Kelly, D.F. and Pontefract, R. (1990), Hepatorenal toxicity in a dog after immersion in Rutland Water. *Veterinary Record*, Nov. 3rd 453-4.
- [25] Turner, P.C., Grammie, A.J., Hollinrake, K. and Codd, G.A. (1990), Pneumonia associated with contact with cyanobacteria. *British Medical Journal*, 300 1440-1.
- [26] NRA (1990), *Toxic Blue-Green Algae*. National Rivers Authority, London.
- [27] Lawton, L.A. and Codd, G.A. (1991), Cyanobacterial (blue-green algal) toxins and their significance in UK and European waters. *Journal of the Institute of Water Engineering and Management*, 5, 460-5.
- [28] Morse, G. K., Lester, J.N. and Perry, R. (1993), *The economic and environmental impact of phosphorus removal from wastewater in the European Community*. London: Selper.
- [29] UK Water Industry Research (UKWIR) (1997), *Influence of phosphate on bacterial growth in water systems*. Report no.97/DW/02/11, London.
- [30] Kolber, E. (1990), *Detergents, the Consumer and the Environment*. *Chemistry & Industry*, No.6, 179-181.
- [31] Sharpley, A. N., S. C. Chapra, R. Wedepold, J. T. Sims, T. C. Daniel, and Reddy, K. A. (1994), Managing agricultural phosphorus for protection of surface waters: Issues and options. *Journal of Environmental Quality* 23:437-451.
- [32] McCann, L. M. J. and Easter, K. W. (1999), "Differences between Farmer and Agency Attitudes Regarding Policies to Reduce Phosphorus Pollution in the Minnesota River Basin." *Review of Agricultural Economics* 21(1), 189-207.
- [33] European Environment Agency (EEA) (1998), *Effects of excessive anthropogenic nutrients in European ecosystems*, EEA, Copenhagen.
- [34] Parr, W., Andrews, K., Mainstone, C.P. and Clarke, S.J. (1999), *Diffuse Pollution: sources of nitrogen and phosphorus*. DETR

- report WS 128/1/115, Foundation for Water Research, Marlow, UK.
- [35] Valsami-Jones, E. (ed.) (2005), *Phosphorus in Environmental technologies: Principles and Applications* London: IWA.
- [36] IEEP (1999), Implementation of the 1991 EU Urban Waste Water Treatment Directive and its role in reducing phosphate discharges. Institute for European Environmental Policy, London.
- [37] Edge, D. (1999), Perspectives for nutrient removal from sewage and implications for sludge strategy. *Environmental Technology*, 20(7), 759-763.
- [38] Greaves, J., Hobbs, P., Chadwick, D. and Haygarth, P. (1999), Prospects for the recovery of phosphorus from animal manures: a review. *Environmental Technology*, 20(7), 697-708.
- [39] Towers, W. and Horne, P. (1997), Sludge recycling to agricultural land; the environmental scientist's perspective. *Journal of the Institute of Water Engineering and Management*, 11, April.
- [40] CEC (European Commission) (2000), Working Document on Sludge, 2nd draft, 12/1/2000 ENV.E.3/LM, CEC, Brussels.
- [41] Werther, J. and Ogada, T. (1999), Sewage sludge combustion. *Progress in Energy and Combustion Science*, 25(1), 55-116.
- [42] Ekins, P. (1999), European environmental taxes and charges: recent experience, issues and trends. *Ecological Economics*, 31, 39-62.
- [43] van der Kleij, M., Dekker, R.H., Kersten, H. and Wit, J.A.W. (1991), Water management of the river Rhine: past, present and future, *European Water Pollution Control*, 1(1), 9-15.
- [44] French Environment Ministry (FEM) (1986), Studies of the Redon river and of phosphorus enrichment of Lake Geneva, Report of FEM Phosphorus – Redon sub-working group. Paris.
- [45] Smith, S. (1997), Environmental Tax Design. In: T. O'Riordan (ed.) *Ecotaxation*, Earthscan, London.
- [46] EUROSTAT (1992), Family Budgets: Comparative Tables Denmark, Greece, France, Ireland, Luxembourg, Netherlands. EUROSTAT, Luxembourg.
- [47] EUROSTAT (1993), Family Budgets: Comparative Tables Belgium, Germany, Spain, Italy, Portugal, UK. EUROSTAT, Luxembourg.
- [48] CFEGP (Commission de Finances, de l'Economie Générale et du Plan) (1999), La Taxe générale sur les activités polluantes et la politique de l'eau. Information report No. 1807, CFEGP, Paris.
- [49] French Ministry of Finance (FMF) (2000), Taxe generale sur les activites polluantes (TGAP). Bulletin officiel de douanes, no. 6421, 4 April 2000.
- [50] European Union Conciliation Committee (EUCC) (2000), Joint text approved by the Conciliation Committee: Directive 2000/EC of the European Parliament and of the Council of establishing a framework for Community action in the field of water policy, conciliation@europarl.eu.int refs. 1997/0067(COD) C5-0347/00 document, EU Parliament, Brussels.
- [51] European Environment Agency (EEA) (1998), Europe's Environment: the second assessment, EEA, Copenhagen.
- [52] Hoesper, S. (1998), Stable states, buffers and switches: an ecosystem approach to the restoration and management of shallow lakes in the Netherlands. *Water Science and Technology*, 37(3), 151-164.
- [53] van der Molen, D., Portlieje, R. and Boers, P. (1998), Changes in sediment phosphorus as a result of eutrophication and oligotrophication in Lake Veluwe, the Netherlands. *Water Research*, 12(11).
- [54] Lang, C. and Reymond, O. (1996), Reversal of eutrophication in four Swiss lakes: evidence from oligochaete communities. *Hydrobiologia*, 334(1-3), 157-161.
- [55] European Environment Agency (EEA) (1999), Environment in the European Union at the turn of the Century, EEA, Copenhagen.
- [56] Key Note (1997), Household soaps & detergents: 1997 Key Note plus market report 11th ed. edited by Zoe Ratcliff, Hampton: Key Note Publications.
- [57] Key Note (1999), Household soaps & detergents: 1999 Key Note plus market report 12th ed. edited by Zoe Ratcliff, Hampton: Key Note Publications.

- [58] Chemical and Engineering News (2000), Rhodia expedites integration of Albright & Wilson, Chem Eng News, 162(21: May 24th), p.28.

Practitioner's Section

Chemische Fabrik Griesheim – Pioneer of Electrochemistry

Dieter Wagner^{*#}

* Dr. phil.nat., Dr. phil. Dieter Wagner, Amselweg 20, D-65779 Kelkheim

Correspondence to: dieter.a.wagner@t-online.de

Abstract: This paper gives a brief survey on the history and the strategies of Chemische Fabrik Griesheim of Frankfurt on the Main. After the foundation in 1856, it had been a middle-sized chemical company manufacturing fertilizers, mineral acids and soda. Due to important innovations, the enterprise developed to a leading producer of heavy chemicals at the end of the 19th century. To improve profitability, it acquired a dyestuff company and joined IG Farben Trust in 1925. After World War II, its activities and plants became parts of other corporations. Most of them are still operating.

Introduction

The emergence of the German dyestuff manufactures in the 1860s had led to a blossoming time of the chemical industry at the end of the 19th century. Before that time, there existed only middle-sized firms producing soda and mineral acids. Chemische Fabrik Griesheim (CFG) of Frankfort on the Main, which celebrates its 150th anniversary this year, belonged to these companies. However, it existed as independent enterprise only up to 1925, when it joined the huge IG Farben trust. Before World War I it had developed into one of the biggest chemical companies in Germany. According to turnover and number of employees it ranged on fourth place behind the "big three" BASF, Bayer and Hoechst. When the Allies disintegrated the IG Farben Industry in 1945, CFG could not be established again, because its biggest production facilities were located in East Germany under the administration of the Soviet Union.

From the Foundation to First Innovation

Ludwig Baist, the founder of CFG, had been inspired by the ideas of the great chemist Justus von Liebig, who published his theory of plant nutrition and mineral fertilization in the early 1840s. The introduction of mineral fertilizers into the market, however, presented more problems than expected. Therefore, one added soda to the product range. In the following two decades CFG developed into one of the approximately 20 chemical companies in Germany manufacturing soda, mineral acids and other chemicals. After 1880 the situation changed dramatically for two reasons: 1. Dyestuff manufacturers, big customers of acids, started their own acid production and 2. the new Solvay process for soda manufacturing turned out to be superior to the Leblanc method, used by CFG and the other soda producers. In 1884, CFG took the opportunity to join a syndicate of soda manufacturers, which aimed to exploit a patent for the production of caustic soda and chlorine by electrolysis of salt. For this complete new technology no experience existed in

the chemical industry at that time. When some experiments in the laboratory looked promising, the CFG took the initiative to build a pilot plant on their Griesheim site. Many obstacles had to be overcome: No electrodes were available which could stand the reaction conditions. The commercial generators did not prove suitable for the electrochemical process. But the plant manager Ignaz Stroof did not give up. In 1890 he could announce that the first production unit in the world for the electrolysis of salt was running successfully.

Growth and Expansion

The cost of electricity, however, was too high at the Griesheim plant, because one had to buy the expensive pit coal of the Ruhr region. Since there existed large deposits of cheap brown coal in Middle Germany, CFG decided to erect a plant with bigger production units in Bitterfeld. Within a very short time CFG was able to supply the market with its new products at reasonable prices. Elektrochemische Werke, a company founded by Walter Rathenau, had also built an electrolysis plant at Bitterfeld. It was not able to compete, gave up and offered CFG to lease their facilities. This put Griesheim within a few years in a position to become the leading supplier of caustic soda, potassium and chlorine

The chlorine-alkali process not only produces these two components but a third one: hydrogen. One tried to use it for heating or even for filling Zeppelin airships. The Griesheim engineer Ernst Wiss developed a burner for iron welding using a mixture of hydrogen and compressed oxygen. Although the management of CFG was reluctant in the beginning, the new process of autogenous welding was successfully introduced in the market. Using a surplus of oxygen the method could be used for cutting metal. For better promotion CFG started cooperation with Air Liquide Company of France, a supplier of oxygen and oxygen production units. Several oxygen facilities were built close to the iron industry in the Rhineland and other regions. As by-products of oxygen fabrication noble gases, especially Argon, Neon and Helium were obtained. In order to find applications for these gases, the Griesheim

scientists experimented with luminophors. In 1913 the first neon lamp was produced in the laboratory.

The production of electrodes for the chloralkali electrolysis also developed to a special field of activities. Electrodes were first obtained by pressing a mixture of crashed coal and tar and heating to 1300°C. The manufacturing of graphite electrodes was taken up in 1916. Besides for electrodes the material can also be used for thermal and corrosion resistant equipment and lining.

Although the main effort concentrated after 1890 on the chloralkali electrolysis and related fields, the other products had not been neglected. The loss of acid sales to the dyestuff companies could be substituted by deliveries to explosive manufacturers. Since Alfred Nobel had invented dynamite, the requirement of sulphuric and nitric acid had picked up. Because the transportation of larger quantities of acids presented problems at that time, CFG erected acid plants close to explosive and gun powder producers in Spandau near Berlin and Küppersteg in the Cologne area.

Chlorine and sodium or potassium hydroxides are simultaneously formed by the electrolysis in a constant ratio. The requirements of soda usually exceeded those of chlorine. In the beginning, chlorine was converted in chloride of lime, which was used in large quantities as disinfectant and for bleaching. In addition, CFG founded in 1882 the subsidiary Mainthal for the manufacturing of organic chlorine compounds. The product range comprised chloroacetic acid, chlorobenzene, benzoic acid, tetrachloromethane, chloral hydrate and others. These compounds were intermediates for pharmaceuticals, dyestuffs and other chemicals or were used as solvents.

The experience gained by chloralkali electrolysis lead CFG to another activity of electrochemical technology. For the manufacture of pure phosphorous, an electric oven had to be designed. In 1895 the first amounts of phosphorous were produced in a pilot plant by heating a mixture of phosphates, coal and sand. Since requirements for matches, artificial fog and metallurgy increased, a larger unit was built in Bitterfeld in 1902. There was also research work done for gaining light metals by electro thermal processes. The plans to

erect an aluminium factory were dropped in 1906 because of low market prices. The manufacturing of magnesium looked more promising. Due to its low weight the metal was of interest for the arising aviation industry. Since further processing of magnesium was difficult, CFG tried to develop better-suited alloys of magnesium and other metals. The efforts resulted in an alloy called "Elektron", which in the following years was widely used for airplane and airship assembling.

Unsatisfying Profitability

Sales increased in 1885, when CFG started to do research in innovative products, from 4,6 Million M to 48,3 Million M in 1905, but in the same period net profits did not keep up with this expansion. They dropped from 8,5 % to 6,2% of turnover. Consequently, the company could only disburse 10 – 16 % dividend to its stockholders compared to 25 – 35 %, which the dyestuff companies were able to pay. For this reason, the management of CFG was looking for an acquisition of dyestuff manufacturers since the beginning of the 20th century. In 1905, the company was offered to buy the Oehler dyestuff factory in Offenbach. The company existed already since 1843, but belonged to the smaller sized dyestuff producers. Sales amounted to 7,5 Million M in 1905 and consisted of dyestuffs and dyestuff intermediates, mainly aniline. However, the acquisition came very late. Because of increasing competition, the big dyestuff companies had formed alliances in 1904. Since CFG put a lot of effort and money in research, sales and profits picked up in the beginning. After 1908 competition became tougher. One was forced to switch to a low price strategy. As shown below, earnings went down considerably.

Million M

	Acids	Soda	Organics	Chloro-organics	Welding Gas	Dyestuffs	Total
1905	0.98	1.66	1.28	0.55	-	0.43	5.88
1906	0.87	1.91	1.33	0.57	0.19	0.68	6.44
1907	1.31	2.14	1.63	0.51	0.41	1.16	7.56
1908	1.02	2.44	1.12	0.57	0.59	1.35	7.06
1909	1.02	2.55	1.32	0.42	0.88	1.15	7.47
1910	1.16	2.81	1.27	0.44	1.22	1.10	7.55
1911	1.16	2.62	1.56	0.36	1.01	0.88	7.56
1912	1.24	2.63	1.63	0.39	1.05	0.25	7.92
1913	1.34	2.95	1.41	0.44	0.99	0.32	8.37

Table 1: Gross profit 1905 – 1913

The decline of profits from 1908 to 1910 was due to a light recession in Germany. The soda business was not affected, but competition was growing in this field, too. Chlorine, chloride of lime and other products of electrolysis also belonged to the soda group. Organics comprised mainly aniline and related goods.

The War and its Consequences

In 1914, at the outbreak of World War I, the number of employees of CFG amounted to 4.708 blue-collar and 950 white-collar workers. The Griesheim factory counted 2.500 employees and the Bitterfeld works approximately 1.500. The others were working at the acid and oxygen plants and at Rheinfelden, a small electrochemical factory, which CFG had also leased from Elektrochemische Werke. The factory was located at the Swiss border and was using hydro-electric power of the Rhine.

Since Griesheim had already manufactured explosives before 1914, it became one of the largest suppliers of explosives in the course of the war. Besides picric acid and trinitrotoluene other explosives like ammonium nitrate, chlorates and perchlorates were manufactured. The armed forces

also ordered phosphorous and magnesium. Because there was no aluminium production in Germany, CFG was asked by the government to join an enterprise for the manufacturing of the light metal. The state was holding 50 % of the shares of the new founded "Vereinigte Aluminiumwerke", CFG and Metallgesellschaft of Frankfurt 25 % each. Until 1918, plants were built in Rummelsburg near Berlin, Horrem/Rhineland and Bitterfeld.

Owing to the increasing fabrication for military purposes, production of civil goods had to be reduced. But still research in non-military fields was possible and resulted in a spectacular invention. Before the war, CFG had experimented with acetylene derivatives, e.g. vinyl acetate and vinyl chloride. When working with these compounds, Fritz Klatte had observed in 1912 that resins were formed when exposed to light. The first polymerisation of polyvinylchloride and polyvinyl acetate had been achieved in the Griesheim laboratories! The new products became of interest during the war as replacement for natural resins, which could not be imported anymore. But due to the difficult process and other priorities only smaller amounts of polymers were manufactured until 1918 in a pilot plant. As soon as natural resins became available again after the war, there was no demand anymore for

polyvinyl plastics. It lasted until the late nineteen twenties before pilot plant manufacturing was taken up again at Bitterfeld and Ludwigshafen. After World War II polyvinylchloride (PVC) became the largest plastic material in the world.

In 1916 another effort was made by the big German dyestuff companies to come to a closer cooperation. As these firms were depending much on exports, they feared a much tougher competition on the world market when the war would be over. On the other hand nobody wanted to give up its independence. Hence in August 1916 the IG Farben Association was founded. CFG joined the alliance as of January 1917. The goal of the association was cooperation and mutual information about sales, new products, expansion plans etc.

After 1918 the need of all kind of goods, which had been accumulated during wartime had to be satisfied. This resulted in a boom of the chemical and other industries. Investment increased, CFG erected new buildings at their locations and modernized equipment. But soon it turned out that the economic recovery would not last. The inflation was eating up the assets of the people and unemployment increased considerably. After the war more than 15.000 people had been employed at the CFG factories. In 1920 the number decreased to 11.200 and in 1924 to 9.700. Within the IG Farben Association negotiations were underway to transform the alliance to a big joint-stock company. The treaty of the IG Farben AG was signed in October 1925 and became effective January 1926. The management of CFG hesitated first to enter the corporation, because its portfolio did not fit well into the business dominated by the dyestuff companies. On the other hand it regarded itself as a dyestuff producer. So finally

CFG also signed and ceased to be an independent enterprise.

The position of CFG within the management of the IG Farben Corporation was not very influential, as its activities did not belong to the strong points of strategy. The Griesheim factory had a hard time to survive. Its facilities for soda and acids were transferred to Bitterfeld or had become obsolete. In the intermediates section the Bayer and BASF plants often had a stronger position. The situation at Bitterfeld was more favourable. The electrolytic equipment was modernized and enlarged. Larger phosphorous ovens were installed; research in the light metal alloys field was intensified. In 1927 a pilot plant for the manufacture of Polyvinylchloride (PVC) was erected, three years later small production facilities. The dyestuff plant at Offenbach suffered most after the IG Farben merger. Manufacturing of many products was discontinued, some departments totally closed due to either streamlining of the assortment or more profitable fabrication conditions at other sites of IG Farben. Luckily in 1912 a new two-component dyeing process had been discovered at the Offenbach research laboratories. The so-called Naphthol AS components were successfully introduced into the market after the war. Increasing sales of Naphthol AS goods ensured the survival of the Offenbach factory.

The Bitterfeld works grew most also during World War II, because light metals but also plastics, phosphorous and chlorine compounds were needed by the military. The number of employees shows the different development of the former CFGE plants under the IG Farben administration.

	Griesheim	Offenbach	Bitterfeld
1923	3.227	1.698	5.382
1925	1.852	1.274	5.239
1929	1.943	732	4.909
1939	905	604	7.966
1944	1.337	549	14.000

Table 2: Employees at former CFG locations 1923 – 1944

Location	Time	Company	Products
Griesheim	1945 - 1952	Chemische Fabrik Griesheim – US Administration	inorganic and organic chemicals, flotation auxiliaries, driers for varnishes and printing inks
	1945 - 1997	Hoechst AG - Werk Griesheim	organic chemicals, intermediates for dyestuffs, pharmaceuticals and pesticides
	1997 - 2003	Clariant GmbH - Werk Griesheim	same as above
	since 2003	Industriepark Griesheim GmbH more than 30 Companies	chemicals, plant protection and carbon products, services
Offenbach	1945 - 1952	Naphthol-Chemie Offenbach US Administration	dyestuffs and dyestuff intermediates
	1945 - 1997	Hoechst AG - Werk Offenbach	dyestuffs, intermediates for dyestuffs, fibres etc.
	1997 - 2001	Clariant GmbH - Werk Offenbach	dyestuffs and intermediates for dyestuffs, pharmaceuticals etc.
	since 2001	Allessa Chemie GmbH	same as above
Bitterfeld	1946 - 1952	Elektrochemisches Kombinat Bitterfeld Kaustic Company (owned by UdSSR)	inorganic and organic chemicals, pesticides, plastics, light metals
	1952 - 1969	Elektrochemisches Kombinat Bitterfeld owned by DDR	same as above
	1969 - 1990	VEB Chemiekombinat Bitterfeld-Wolfen	inorganic and organic chemicals, pharmaceuticals, pesticides, plastics, light metals, fibres, films, dyestuffs
	1990 - 1993	Chemie AG Bitterfeld-Wolfen	chemicals, plastics, films
	1993 - 1997	Chemie GmbH Bitterfeld-Wolfen	same as above
	since 1997	Chemiepark Bitterfeld-Wolfen more than 30 companies	chemicals, pharmaceuticals, industrial gases, light metals, glass products
Rheinfelden	1946 - 1953	Chlorbetriebe Rheinfelden AG French Administration	chlorine, vinyl chloride and other related chemicals
	1953 - 1989	Dynamit AG Troisdorf Werk Rheinfelden	chlorine, vinyl chloride, silicon tetrachloride and other silicon compounds
	1989 - 2001	Hüls AG Marl – Werk Rheinfelden	chlorine, sodium methylate, silicon compounds
	since 2001	Degussa AG	silicon compounds

Table 3: Succession Companies of CFG after 1945

After the war Sigrí Elektrographit GmbH, a joint venture of Siemens and Hoechst AG, was running the carbon business. In 1991, the company merged with Great Lakes Carbon of

USA to form SGL Carbon AG, a leading producer of carbon and graphite goods. A joint venture was also formed by Hoechst AG and Adolf Messer GmbH for the industrial gases and welding products. The shares of Hoechst were sold in 1999

to Messer Industrie GmbH and in 2004, the Messer Group GmbH took over the entire company.

Summary

In the first decades after its foundation, the management of CFG was following a conservative strategy. However, when the company was experiencing more and more into difficulties in the 1880s, the executives moved courageously and successfully into a completely new field of chemical technology. They also did not hesitate to relocate the new production to places where conditions were more favourable. After the company had gained a leading position in the heavy chemicals market, it followed up its innovative policy resulting in new gas welding technology, industrial gases and carbon products. Although it took quiet some time to convert the invention of vinyl polymers into economic success, CFG could claim to have produced these polymers on an industrial scale for the first time. Despite its achievements in heavy chemical industry, CFG was not operating as profitable as other chemical firms, manufacturing products that are more sophisticated such as dyestuffs and pharmaceuticals. Therefore, the management of CFG changed its strategy, neglected to update its innovative products and procedures and bought a small dyestuff producer. Nevertheless, the action did not yield the expected result, because the dyestuff market had already passed over its climax, but it paved the way to the merger of CFG into IG Farben Industries.

The name of Chemische Fabrik Griesheim is forgotten, but its tradition is alive in its succession companies and its contribution to basic chemical technology. Finally, CFG has gained merits as main initiator of a new industrial region for chemistry in Middle Germany, called "Chemiedreieck Halle/Merseburg".

References

Archives Hoechst AG at Histocom GmbH, Frankfurt a.M.-Höchst: Minutes of the board of directors of CFG 1856 – 1925, records of the stockholders meeting, various reports and correspondences (c/2/3/b – c/3/4/a).

Raschen, H., Hofmann, P. (1937), 75 Jahre Chemische Fabrik Griesheim-Elektron, Frankfurt a.M.

Pistor, G. (1958), Hundert Jahre Griesheim 1856 – 1956, Tegernsee.

Wagner, D. (1999), Innovation und Standort, Geschichte und Unternehmensstrategien der Chemischen Fabrik Griesheim 1856 – 1925, Darmstadt.

Chronological Table of the History of Chemische Fabrik Griesheim

- 1856 Foundation of the company by Ludwig Baist, production of fertilizer and mineral acids
- 1859 Production of Soda
- 1881 Erecting of aniline plant
- 1884 Syndicate for exploiting a patent for chloralkali-electrolysis
- 1888 Manufacture of carbon electrodes
- 1889 First issuing of CFG shares at the Frankfurt stock exchange, fabrication of explosive picric acid
- 1890 First unit for chloralkali electrolysis running at Griesheim
- 1894 Plant for chloralkali electrolysis built at Bitterfeld
- 1900 Electric oven for phosphorous production built at Bitterfeld
- 1902 Developing of gas welding procedure
- 1905 Acquisition of the dyestuff company Karl Oehler at Offenbach
- 1908 Construction of oxygen plant at Griesheim and other locations
- 1909 New light metal alloys presented on air show at Frankfurt
- 1912 First polymerisation of vinyl chloride to plastic materials, developing of Naphtol AS dyeing procedure
- 1914 World War I, production of various explosives
- 1916 CFG joins IG Farben Association
- 1917 Foundation of Vereinigte Aluminiumwerke, CFG holds 25 % of shares
- 1919 Griesheim plant occupied by French military
- 1925 Merger to IG Farben Aktiengesellschaft
- 1945 Griesheim plant closed by US army, Bitterfeld under administration of UdSSR
- 1946 US Administration, resumption of production
- 1952 Griesheim and Offenbach part of newly founded Hoechst AG
- 1965 Joint venture for industrial gases and welding with Adolf Messer GmbH
- 1967 Sigri Elektrographit GmbH founded, a joint venture with Siemens for carbon products
- 1990 State owned Bitterfeld works transformed to Chemie AG Bitterfeld-Wolfen
- 1991 Fusion of Sigri Elektrographit and Great Lakes Carbon Corp. to form SGL Carbon AG.
- 1997 Acquisition of Griesheim and Offenbach plants by Clariant AG of Switzerland, foundation of Chemiepark Bitterfeld

Erratum

In: Derera, N. F., Nagy, N., Hoxha, A. (2005) Condiment paprika research in Australia, *Journal of Business Chemistry* 2 (1), pp. 4-18.

The content of the “Name/identification” column in Table 6 on page 14 needs to read “208” instead of “HM2”, “248” instead of “HM3” and “210” instead of “HM5”. The corresponding content in column “Possible gene/genotype” needs to read “*ms3*” for “208”, “248” and “210”.

The same corrections should be noted in table 8 on page 16. In the column “Male sterile line”, the content needs to be “208” instead of “HM2”, “248” instead of “HM3” and “210” instead of “HM5”.



Special Issue

In cooperation with the 3rd International Conference on Intellectual Capital, Knowledge Management and Organisational Learning, the Journal of Business Chemistry will publish a special issue on Knowledge Management in January 2007. Selected articles of the conference will be published in this special issue. Other submissions are possible but have to be sent to submit@businesschemistry.org until the 27th of October.

3rd International Conference on Intellectual Capital, Knowledge Management and Organisational Learning (ICICKM 2006)

19-20 October 2006

Pontificia Universidad Católica de Chile, Santiago, Chile

This conference, which provides the latest research and thinking in the field, invites abstracts for suggested papers on a wide range of topics and scholarly approaches including theoretical and empirical papers employing qualitative, quantitative and critical methods. Action research, case studies and research in practice are welcomed approaches. Work-in-progress, panel discussion, proposals for workshops and tutorials are also invited. Possible topics include, but are not limited to:

Frameworks for conceptualising KM; parameters of the field of study; knowledge creation and sharing mechanisms; knowledge asset valuation models; impact on organisational learning; impact on business strategy; architectures for KM systems; integration of knowledge from different groups in an organization; knowledge sharing between different groups in an organization; how to initiate KM; resourcing KM; KM case studies; the evaluation of KM; KM and the Web and e-Business; structural capital; inter-organisational relationships; strategic alignment; intangible assets; organisational learning; intellectual capital; economic intangible assets; organisational coaching. Submissions relating to organizational learning, intellectual property and knowledge management in the chemical industry (nanotechnology, oil-and-gas...), pharmaceutical industry, biotechnology and agronomics are particularly welcomed.

The conference will be of interest to academics and practitioners who are involved in the study; management, development and implementation of knowledge management initiatives, intellectual capital issues and organisational learning opportunities and challenges.

Further details about the conference, including information of how to submit, are available at: <http://www.academic-conferences.org/icickm/icickm2006/icickm2006-home.htm>

Special registration rates are available for readers of the Journal of Business Chemistry. Quote MJBC as the discount code on the registration form for a 10% discount on the advertised rate.



*A part of the EBSCO
Information Services group.*

www.ebsco.com

EBSCO Publishing / EBSCOhost is the registered trademark of EBSCO Publishing.

0 to 160 kph in 3.6 seconds –

More than enough time for Henkel products to show what they are capable of.



Systems solutions from Henkel – when it comes to top performance.

Powerful brands from Henkel offer proven systems solutions packed with all the experience of the global market leader in bonding, sealing and surface treatments.



Like Team McLaren Mercedes, leading companies rely on the Henkel mix of innovative high-tech products, unrivaled process expertise, and the comprehensive services provided by its worldwide network of R&D specialists and sales engineers.

www.henkel-technologies.com

Quality from 

Adhesin

Bonderite

Hysol

Liofol

Loctite

P3

Technomelt

Teroson