FORSCHUNGSSTELLE FÜR UMWELTPOLITIK
Freie Universität Berlin
Fachbereich Politik- und Sozialwissenschaften
Otto-Suhr-Institut für Politikwissenschaft

Forschungsstelle für Umweltpolitik

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Environmental Policy Regulation by Voluntary Agreements: Technical Innovations for Reducing Use and Emission of EDTA

Jobst Conrad

FORSCHUNGSSTELLE FÜR UMWELTPOLITIK
Freie Universität Berlin
Fachbereich Politik- und Sozialwissenschaften
Otto-Suhr-Institut für Politikwissenschaft

Ihnestr. 22
14195 Berlin

telefon +49-30-838 566 87
fax +49-30-838 566 85
email ffu@zedat.fu-berlin.de
internet www.fu-berlin.de/ffu/

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Abbreviations

AIS	Association Internationale de la Savonnerie, de la Detergence et des Produits d'entretien
AIF	Arbeitsgemeinschaft industrieller Forschungseinrichtungen (federation of industrial cooperative research bodies)
ARW	Arbeitsgemeinschaft der Rhein-Wasserwerke (working group of rhine water utilities)
AWBR	Arbeitsgemeinschaft Wasserwerke Bodensee-Rhein (working group of lake Konstanz water utilities)
AWWR	Arbeitsgemeinschaft der Wasserwerke an der Ruhr (working group of Ruhr water utilities)
BASF	Badische Anilin und Soda Fabriken
BfG	Bundesanstalt für Gewässerkunde (federal agency of hydrology)
BGA	Bundesgesundheitsamt (federal health agency)
BgVV	Bundesamt für gesundheitlichen Verbraucherschutz und Veterinärmedizin (federal agency for consumer health and veterinary medicine, established separately after the dissolution of the BGA in 1994)
BGW	Bundesverband der Gas- und Wasserwirtschaft
BMBF	Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie (federal ministry of education and research)
BMFT	Bundesministerium für Forschung und Technologie (predecessor of BMBF till 1984)
BMG	Bundesministerium für Gesundheit (federal ministry of health)
BMI	Bundesministerium des Innern (federal ministry of interior, responsible for environmental affairs till 1986, when the BMU was established)
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (federal ministry of the environment, nature conservation and nuclear safety)
BMWi	Bundesministerium für Wirtschaft (federal ministry of economic affairs
BUA	Beratergremium für umweltrelevante Altstoffe (advisory council for environmentally relevant existing chemicals
CEFIC	Conseil Européen des Fédérations de l'Industrie Chimique
DBU	Deutsche Bundesstiftung Umwelt (federal German environment foundation)
DFG	Deutsche Forschungsgemeinschaft (German research society)
DVGW	Deutscher Verein des Gas- und Wasserfaches (German association of gas and water utilities)
EP	environmental policy
ETP	ecology-oriented technology policy
ESWE	a water utility based institute of water research and water technology
IHO	Industrieverband Hygiene und Oberflächenschutz (industry association hygienic and surface protection)
IKW	Industrieverband Körperpflege- und Waschmittel (industry association body care and washing agent)
LAWA	Länderarbeitsgemeinschaft Wasser (working group water of German states)
MELF	Landesministerium für Ernährung, Landwirtschaft und Forsten (state ministry for agriculture)
NGO	nongovernmental organisation
PTWT	Projektträger Wassertechnologie (research project management body "Water technology and sludge treatment")
R&D	research and development
TEGEWA	Verband der Textilhilfsmittel-, Lederhilfsmittel-, Gerbstoff- und Waschrohstoff-Industrie (industry association of raw materials and auxiliary products for textiles, leather, tanning and washing agents)
TZW	Technologiezentrum Wasser of the DVGW (technology centre water)

UBA	Umweltbundesamt (federal environmental agency)
VCI	Verband der chemischen Industrie (association of the German chemical industry
WaBoLu	Institut für Wasser-, Boden- und Lufthygiene (the institute is part of UBA since the dissolution of the BGA in 1994)

ADA	alanine diacetic acid
DTPA	diethylene triamine penta-acetic acid
EDDS	ethylene diamine di-succinic acid
EDTA	ethylene diamine tetra-acetic acid
IDS	imino di-succinic acid - (sodium salt)
ISDA	iso serine di-acetic acid
MGDA	methylglyzine di-acetic acid
MSA	maleic acid anhydride
NTA	nitrilo tri-acetic acid
PASP	polyaspartic acid sodium salt
PDTA	propylene diamine tetra-acetic acid

Summary

This case study investigates bargaining and innovation processes around efforts to reduce and to substitute production and use of EDTA between 1985 and 1999. Environmental policy succeeded in stimulating efforts to significantly reduce EDTA release, in particular by aspiring to a voluntary declaration and subsequent voluntary agreements. Supported by continuous debate in EDTA meetings and by the eigen-dynamic of commitments made by participating actors, these efforts led to substantial results, though not as much as had been envisaged. The environmental innovations arising typically were technical process innovations or a combination of product and process innovation rearranging and optimising chemical processes in various industries using EDTA. Concerning producers and suppliers of chelating agents, their EDTA-related innovative efforts were embedded in general research programs elucidating the pronounced strategic capabilities of large corporations in managing innovations. Without significant public funding policy making and interpolicy coordination of environmental policy and ecology-oriented technology policy in most cases had at best an indirect impact on these innovation processes reinforcing them to some degree by promoting regulatory framework conditions and monitoring programs. Consequently, various relatively separated knowledge, business and regulatory networks originated from these EDTA-related innovative efforts. Comparing different R&D projects leading to technically viable environmental innovations of reducing, substituting, or degrading EDTA (use), the central importance of corporate capacities and market opportunities for their successful diffusion becomes obvious. Thus, serious obstacles to the innovation processes referred more to their social than to their technical and time dimension. Altogether, environmental policy successfully organised multiple efforts to reduce EDTA release on the basis of voluntary agreements in Germany. These voluntary agreements enhanced, but did hardly induce corresponding environmental innovations, mainly in industry, and also contributed to learning processes among the actors, participating in EDTA discourse and politics, in the direction of a more holistic (policy) perspective towards ecological sustainability.

1 Purpose and methodology of the case study

This case study investigates bargaining and innovation processes around efforts to reduce and to substitute production and use of EDTA (ethylene diamine tetra-acetic acid) between 1985 and 1999.[1] EDTA is a powerful chelating (organic sequestering) agent used since 1939 which binds cations and thus primarily inactivates metal ions which could cause undesired reactions, otherwise. EDTA has many favourable properties when used in chemical engineering processes, such as high stability of metal-EDTA complexes, solubility in water, insolubility in organic solvents, no volatility, high stability against hydrolysis, i.e. resistance against strong acids and lyes. Therefore, EDTA is used as an additive to sequester undesirable cations in many areas, such as washing and cleansing products, cleaning, electroplating, water softening, polymerisation for industrial purposes, photographic industry, textiles, pulp and paper, pharmaceuticals, cosmetics, food and agriculture. Nearly all of these applications will eventually result in the release of EDTA to the environment, in many cases via the sewage system. EDTA biodegradability is low so that heavy metals bound to EDTA may well be transported in water. In order to keep EDTA concentration in rivers and drinking water low, particularly in Germany efforts have been undertaken since the late 1980s to reduce EDTA emission by substitution and changes in technical processes.

The main purpose of the case study is to study the influence of regulatory networks and framework conditions upon corresponding innovation processes, particularly the role of environmental policy (EP) and technology policy (TP) and their mutual coordination within this context (IIUW 1998).

The study is mainly based on 17 loosely structured interviews with key persons involved in these regulatory and innovation processes, either on a face-to-face basis (8 interviews lasting 1 to 2 hours) or by telephone (9 interviews lasting between 15 and 45 minutes). In addition, UBA allowed me to study its EDTA files containing hundreds of records with position papers, meeting documents, surveys of EDTA measurements, research papers etc. Furthermore, some other literature and documents dealing with EDTA and its substitutes have been studied. The draft report of the case study has been circulated to the interviewees for critical reading and comments, which have been taken into account according to my personal assessment, provided that I received them. Finally, supplementary (corrective) information, obtained at the 14. EDTA meeting in November 2000, in which I participated, has been added to the draft report.

The interviews were made with representatives of the following institutions (index t = telephone interview): BMU (2_t), UBA (1), technical university Braunschweig, institute of biochemical engineering (1), research center Karlsruhe, institute for technical chemistry, section water technology (1_t), DVGW research unit, university of Karlsruhe (1_t), ESWE institute for water research and water technology (1), BASF (1), Bayer AG (1_t), DiverseyLever (1), Fuji (1_t), Kodak AG (1_t), MILEI (1_t), IHO (1), TEGEWA (1), VCI (1_t), association of the photochemical industry (1).

[1] It has been funded by the EU Commission as part of the ENVINNO-project (IIUW 1998).

The details of regulatory networks and innovation processes were successively recognised and understood during the various subsequent interviews, mainly conducted in December 1999, so that critical questions about controversial issues and less openly presented intangibles could be posed on a better knowledge basis particularly in the later interviews.

From a methodological point of view, the demand to perform an (in-depth) case study within one month of workload necessarily implies limited validity of its results for several reasons.

1. It allows hardly any (systematic scientific) verification procedures beyond confronting individual interviewees with diverging opinions of other persons interviewed and beyond asking the interviewees for corrections of and critical comments on the draft report.[2]
2. Neither detailed analysis of all EDTA files of UBA, nor study of relevant contextual literature on environmental impacts of chelating agents, on biodegradability, on contamination of substances and waters, on business conditions in the various application areas, on corporate strategies, and on varying regulatory contexts were feasible.
3. The whole setting of overlapping EDTA stories is too complex to allow a detailed analysis and description of specific innovation processes and of informal agreements and arrangements behind the scenes within the manifold specific EDTA case histories pointed out below. Thus, a scientific assessment of the validity of the case history and of its interpretation in social, political and ecological terms presented here was not possible either.
4. The presentation of the case study on about 50 pages does not allow to eventually discuss subtleties and different possible interpretations of the innovation processes reconstructed.

2 The physical and social setting

This section describes the physical and social setting of EDTA-related regulations and innovations by pointing out the essential structure of (potential) ecological and health problems due to EDTA, the profile of EDTA utilisation, some relevant legal and market conditions, and the feasible options to master the EDTA problem environmentally.

EDTA as a chemically rather stable powerful chelating agent inactivating metal ions offers very favourable properties for industrial purposes. However, although not strictly connected to these properties, it is normally not readily biodegradable as an anthropogenic substance, too. Whereas its genuine environmental and health risks appear to be small and may be judged acceptable, its potential indirect impacts particularly by chelating heavy metals and thereby channelling them through waste water treatment plants may well be hazardous for the environment and human health

[2] This methodical intricacy has to be underscored, in particular, when taking into account the varying cognitive framings of the EDTA issue by different actors, described below.

though rather improbable to occur under normal circumstances (cf. AIS 1987, BUA 1996). According to the precaution principle (laid down in the German drinking water ordinance), however, man-made substances should not be contained in drinking water in non-marginal concentrations, and their elimination out of water resources should not require special (technical) provisions by water supply utilities.

Furthermore, substitutes of EDTA with appropriate complexing characteristics may well tend to imply similar and other new, yet (first) unknown environmental impacts. In addition, evaluating the relative preferability of EDTA versus substitutes has to take into account ecological trade-offs, for instance better biodegradability versus potential cancer potential of NTA, trade-offs between technical effectiveness and environmental compatibility (e.g. strong versus weak complexing agents), and economy-ecology trade-offs, for example high production costs of a suitable substitute that, however, may be applied effectively for quite special purposes only. Thus, even opposing judgements about the need to reduce and to avoid EDTA emissions for environmental or health reasons, and therefore about the ecological value of R&D efforts to substitute EDTA may well claim legitimacy.

In view of the manifold application fields of EDTA and of its favourable properties compared to potential substitutes no universal substitute suitable for all purposes is likely to exist, as discovered and accepted during the early 1990s. As a consequence, quite different innovative efforts have been necessary to avoid or to reduce EDTA release. Because of their limited reach and uncertain (economic) advantages success or failure of these (often small and adaptive) innovations mainly depend on the specific framework conditions prevailing in a country at present, and typically not on a scientific break-through.

In addition, measurements of EDTA concentrations in rivers, which indicate overall (local) emission quantities, tend to show quite some variability according to their arrangement and criteria. Furthermore, recording amounts of EDTA sold does not simply reflect the amounts of EDTA applied in a country because of significant EDTA exports and imports. The same holds true for EDTA concentrations in rivers, which reflect exports and imports of EDTA emissions by a country. Finally, EDTA users frequently do not know the composition of their chemical products applied, and therefore if they use EDTA or not.[3] Thus, reduction and avoidance of EDTA emissions require corresponding knowledge by quite a few actors involved in respective uses.

In Germany, the total amount of EDTA used was around 4.500 tons during the early 1990s with an overall declining tendency (25% -30%), whereas it was around 30.000 tons per year in Western Europe with a slight trend upwards.[4] Release into wastewater and rivers amounted to around 1.000 tons in Germany annually with a decrease of about 25% - 30% during the 1990s. The distribution of different areas of EDTA application shows about the following pattern in Germany, though with large relative

[3] However, EDTA is meanwhile listed as a relevant substance for use of detergents in many manuals.

[4] This was accompanied by an increasing use of NTA and DTPA as major EDTA substitutes in Germany, less observed on the EU level.

alterations during the 1990s and in other countries: photo chemicals 30%, cleaning and detergents in business 25%, cleaning and detergents in households 2%, food and agriculture 5%, pharmaceuticals and cosmetics 3%, water treatment 1%, pulp and paper 2%, textiles 3%, flue gas desulphurisation in the power plant Buschhaus 9%[5], others 20%. Large decreases could be observed particularly for cleaning and detergents in households (application of substitutes), photographic processing (application of the substitute PDTA, rearrangements of photochemical technology), textiles, cosmetics, the galvanic industry (nearly 100% because of the prohibition to release EDTA into waste water), and partly for pulp and paper.[6] The main areas of EDTA application that are still able in 2000 to contribute considerably to reduce EDTA use relate to industries developing photos and using detergent products.

In principle, there exist four (technical) options of reducing and avoiding EDTA release in industrial processes:

1. renunciation of EDTA, when complexing of heavy metals is not really necessary,
2. reduction of EDTA use by rearranging industrial processes towards better utilisation of EDTA, for instance via recycling and integrated production cycles,
3. degradation of EDTA into ecologically harmless metabolites by biochemical decomposition, by burning, or by reusing EDTA containing wastes, as in flue gas scrubbers, that finally burn or decompose EDTA.
4. development and application of EDTA substitutes.

Now the viability and advantage of each option depends on the prevailing economic, sociopolitical and legal conditions, which show quite some complexity in their arrangements and vary considerably from case to case, as illustrated by the following examples.

NTA is recommended as a substitute of EDTA within reasonable limits by UBA, whereas NTA use is not recommended or even restricted to special applications in some other countries because of its assumed but not finally approved potential carcinogenicity, which undermined the willingness of suppliers[7] and users to substitute NTA for EDTA in Germany, too.

The substitute MGDA produced by BASF is not always a technically feasible substitute, rather expensive, and therefore only slowly and partially accepted by suppliers and users of complexing agents.

Using the equally slowly biodegradable complexing agent DTPA in the pulp and paper industry has led to similar DTPA concentrations measured in rivers despite lower

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5 Because waste management occurs by burning and underground deposition of filter ashes, EDTA is not released into surface waters in this case.

6 This holds for Germany but not for quite some other European countries, because DTPA was applied instead of EDTA in Germany, mostly from the very beginning of peroxide bleaching, with EDTA, however, still arising as a metabolic decomposition product of DTPA.

7 In this report the manufacturers of EDTA-containing products such as detergents or cleaning products are termed suppliers, or formulators occasionally, because they buy EDTA from EDTA producers in order to formulate their products, which they then sell to their customers as the actual EDTA users.

amounts needed per production unit so that the EDTA problem has not really been solved but only shifted to the environmental and health hazards of another complexing agent. Furthermore, EDTA is a metabolite of DTPA, representing ca. 30% to 50% of its biological decomposition.

Because the environmental, health and labour safety hazards of EDTA have been still assessed by a risk assessment procedure of the EU Commission (UBA 2000) until recently, the results of which will influence the future (legal) acceptability of EDTA use, other independent efforts of EDTA reduction attracted less (probably costly) support by user companies beforehand.

Because there are no unequivocally compelling arguments in favour of EDTA reduction and avoidance, user companies see no convincing reason to invest in costly rearrangements of their production or cleaning processes for this purpose.

Water utilities oppose for good economic reasons legal requirements based on health criteria to invest in further water treatment devices to eliminate unwanted materials from water, if this end-of-pipe solution can be avoided at the emission source of such undesired substances.

Biological degradation of EDTA may well offer a comparatively cheap option to EDTA release into rivers, but producer and user companies may prefer the application of EDTA substitutes for reasons of sunk costs or convenience, particularly if biological degradation requires rather sophisticated treatment plants on the user side.

3 Case history

The following section describes the case history at three levels: political bargaining processes providing the framework conditions and political pressure to reduce EDTA release; EDTA-related interests and interaction pattern of producers, suppliers and users forming these reduction efforts; and selected R&D efforts to realise in practice the envisaged reduction objectives.

3.1 Annual EDTA meetings and voluntary declarations

3.1.1 History and formation of the EDTA declaration

In Germany the phosphate limiting ordinance in 1980 set a limit to phosphate contents in detergents and cleaning products and induced, among others, efforts to search and develop organic phosphate substitutes, such as NTA. The environmental impacts of NTA on water bodies were investigated from 1981 to 1984 in a study commissioned by the BMI, at that time still responsible for environmental affairs. Open questions, formulated in this study, were dealt with in subsequent research projects from 1985 through 1990, their results being presented in a final colloquium and published in 1991 (Kernforschungszentrum Karlsruhe 1991). Altogether, it was concluded that NTA is well biodegradable and has rather limited environmental impacts so that its limited utilisation appears tolerable.

These research projects requiring close to 1,5 million Euro were jointly funded by the BMBF, the BMU and by NTA-related industries (i.e. IKW, BASF), which also agreed to a voluntary self-obligation in 1986 to use NTA as little as feasible in order to avoid eventual prohibition of NTA. Significant politico-economic driving forces in this direction resulted from the minimization rule of health policy for anthropogenic substances, particularly in drinking water, even without regard of the still questionable carcinogenic risk potential of NTA, from corresponding pressure of water utilities against NTA release into water bodies, and from competing interests of large corporate producers of detergents and washing agents (cf. Henkel, Procter & Gamble) concerning the phosphate substitutes Zeolite A and NTA. This context explains why NTA met ambivalent assessments by relevant actors later, when discussed as reasonable substitute of EDTA in respective EDTA meetings.

Now, within monitoring programs of NTA concentrations in aquifers and rivers during the mid-1980s, considerable EDTA concentrations up to 50 or even 100 µg/l were detected, too, that were much higher than those of biodegradable NTA (<10µg/l).[8] These incidental unforeseen findings, together with the not yet well understood remobilisation effects of EDTA on heavy metals, were the starting point of intentional EDTA reduction efforts, investigated in this case study, because they generated concern in key actors such as water research institutes, water utilities, water authorities, environmental ministries and EDTA producers.

On the one hand, BASF as the main German producer of EDTA was aware of the controversial (public) debate about NTA use and risks and the respective general minimization objective of NTA use and thus NTA production, and had an interest to maintain the positive atmosphere of a laboriously established dialogue between the chemical industry and the water supply industry. And BASF was already engaged in general wastewater reduction programs, and made efforts to develop marketable EDTA substitutes. Therefore it was clearly interested in avoiding public controversy on EDTA with exaggerated risk perception and corresponding bureaucratic overregulation, in a pragmatically and technically reasonable approach towards probable reduction of EDTA use, and in getting a reliable assessment of the probable future regulatory handling of EDTA and its potential substitutes. On the other hand, the BMU was interested in acquiring sufficient information about the size and application areas of EDTA use as well as about its environmental impacts and possible substitutes, in - after public debate about phosphate and NTA emissions - avoiding public criticism of insufficient environmental care for chelating agents, and in arriving at a kind of covenant together with relevant social actors to reduce EDTA emissions. This latter objective was considered favourable because the BMU was well aware of legal problems in principle to forbid EDTA, for its risks did hardly justify such a ban which -

8 According to BASF (1987) EDTA concentrations in previous years had been higher than around 1986, if they could have been measured, because of higher amounts of EDTA use.

even if passed - could not be rapidly implemented either because of predictable accompanying law suits.

It was within these framework conditions that the responsible ministerial director took action from 1986 on to arrange a round table meeting on EDTA with key actors in order to exchange information and to generate a framing and management perspective on this issue. In September 1987 14 persons participated in the first so-called EDTA meeting, mainly representing environmental policy (BMU, UBA (7)) and EDTA production (BASF (3)), supplemented by water research, health policy (BGA-WaBoLu) and agricultural policy. On this meeting various aspects of EDTA use were presented by BASF (see BASF 1987) concerning amounts used, market structure, options to reduce release into water bodies, possible water treatment technologies, scepticism of non-German industry concerning the need to reduce EDTA use, and an environmental impact assessment. Conclusions were drawn concerning different activities to gain more detailed information about application areas of EDTA, about substitution options for EDTA, about environmental and health impacts and related water standards, and about EDTA concentrations in surface waters, to promote appropriate measures of reducing EDTA emissions in various industries, and to reflect the relevance of licensing EDTA as a food additive by the EU Commission. This kind of issues remained major topics on the agenda of EDTA discussions and meetings till to the present.

Accompanying (informal) discussions served to disseminate factual knowledge and to clarify misinterpretations of EDTA use and impacts, for instance concerning its slow biodegradability, the need to distinguish primary use of NTA in detergents from the use of EDTA in many areas, detergents being only one of them, or the limited remobilisation of heavy metals by EDTA in rivers due to its still insignificant concentration and to the already bound metal ions in EDTA-chelating complexes released in waste water.

The overall development of EDTA policy and regulation can be characterized as a development from controversy to cooperation with the voluntary EDTA declaration in 1991 as the major turning point.

Controversial positions due to diverging interests, that can be found in the position papers presented in the following years by different actors such as UBA, BGA, VCI and others, were reflected in differing EDTA-related cognitive problem definitions, evaluative judgements, measures recommended, and assumptions about the motivations underlying the activities of their opponents. Conflicts existed not only between economic interests of EDTA producers and users, and ecological interests of EDTA avoidance advocates, but also between differing EP approaches, advocated by waste water and water quality representatives favouring emission standards or quality targets for EDTA, between environmental policy and health policy concerning in particular the suitability of NTA as an EDTA substitute, between different EDTA producers and suppliers as well as between research groups developing differing solution options, each favouring just those EDTA substitutes or biodegradation systems developed and advanced by itself, respectively.

Thus, UBA for instance recommended in 1989/90 legally non-binding environmental quality targets of 1 or 10 µg/l for stationary and flowing surface waters, respectively, arguing with toxicity, induced algae growth and limitations to chelated heavy metals. In view of the ban on atracine in 1991, the limit value of 0.1 µg/l for single pesticides in drinking water, and the comparatively very high EDTA concentrations found in rivers, water research institutes and water supply utilities demanded a ban on EDTA if possible because anthropogenic and not readily biodegradable substances should not be released into water bodies and not contained in drinking water, and - in accordance with the polluter-pays-principle - the user of EDTA and not the water utilities suffering from EDTA release should care for the elimination of EDTA, as by ozoning techniques. The BGA or BgVV, respectively, were cautious not to condemn EDTA and to argue in favour of its careful use because of its low health risks and the potential carcinogenicity of the substitute NTA. Different technological options to substitute or to degrade EDTA were promoted and extolled by their corresponding innovation networks and evaluated sceptically and subtly rejected by the competing innovation groups.

On the other side, the VCI underlined the largely given environmental compatibility of EDTA and indicated the insufficient scientific validity of studies pointing out environmental impacts of EDTA because of their dependence on certain physical and chemical conditions not representative for real world conditions, because of studies with contrasting results, and because of unproven assumptions made. Furthermore, the VCI emphasized the feasibility of EDTA elimination technologies such as ozoning for water utilities, if this should be considered necessary at all because the EDTA concentrations in waters typically observed would imply no health risk. EDTA users interested in avoiding the costs of rearranging the processing combinations in their plants argued with their ignorance of the formulae in the detergents and cleaning agents they use, the role of imported EDTA in case of a national ban on EDTA production, and the environmental compatibility of EDTA, too.[9]

Assumptions about the underlying intentions of their opponents probably show aspects of projection of their proponents confirming the validity of the Thomas theorem[10]. Thus, on the one hand, representatives of EDTA producers and users interpreted the initiative action of BMU administration to reduce EDTA emissions mainly as a means to protect the environmental minister against external criticism of insufficient action, or interpreted the strong protest of water supply utilities against EDTA as proxy conflict because of its tolerable environmental impacts, or criticized lacking coordination between federal and local policy, between chemicals policy and water policy, as well as lacking pragmatic political flexibility, thereby ignoring a similar lack of coordination between EDTA producers, suppliers and users, and lacking flexibility to rearrange their equipment and processing technology in order to reduce EDTA use and release. Representatives of UBA, on the other hand, tended to insist on strict and detailed regulations because of

[9] From these types of reasoning it is obvious that different cognitive frames of actors were advanced by the actors involved in the EDTA policy game according to their interest in further utilising, or in reducing and avoiding EDTA.

[10] If man defines a situation as real, it will be real in all its consequences.

the assumed inherent tendency of industries to circumvent any imprecise or non-compulsory environmental regulation or agreement.

Taking into account existing framework conditions, the strategy to follow a consensual approach towards a voluntary agreement of relevant actors in favour of reducing EDTA emissions appeared to be not only a reasonable, but probably the best EP option to arrive at protective environmental action beyond mere exchange of information. The relevant framework conditions were the following ones:

1. strong protest and pressure of water utilities in view of comparatively high EDTA concentrations in rivers,
2. no scientifically proven severe environmental or health risks of EDTA justifying its legal ban,
3. therefore little chance to rapidly enforce - without long lasting law suits - a legal prohibition of EDTA and to implement it,
4. a manifold and internationally shaped market structure of EDTA supply and use with varying national (regulatory) EDTA arrangements hard to control by (national) policy prescriptions,
5. however, trustworthy threat of regulatory arrangements forcing industries to avoid EDTA release according to then issued formal administrative rules.[11]

Because neither the UBA proposal to introduce quality standards of 10 µg/l or less as recommended objectives to be reached for EDTA concentrations nor counter suggestions of the VCI (and some other industry actors) aiming at 50 µg/l had a chance to become generally accepted, the idea to reduce EDTA load in water bodies by a certain percentage over a certain period of time, which was first articulated by a representative of the BfG in 1990 and then consequently pursued by the responsible BMU official, gained growing support by the relevant actors. That happened because EDTA-related industries saw an economically realistic potential to halve total EDTA loads by reducing EDTA release by one third, by substituting one third of EDTA applications, and by keeping the last third of EDTA uses, and because water utilities and emission oriented environmentalists in EP-related institutions perceived this flexible reduction concept as better than nothing, after their preferred stricter EDTA limitation strategies proved politically unviable.

Following about another year of bargaining and persuasion within and outside the newly established practice of annual EDTA meetings, the EDTA declaration was agreed upon, published in the joint ministerial periodical gazette in 1991, propagated subsequently, and supported by additional actors.[12] The EDTA declaration as a legally non-binding document expressed the willingness of the signatories, namely BMU, BMG, BMFT, VCI, BASF, BGW, DVGW, ARW, AWBR and AWWR, to strive for a reduction of EDTA load in rivers and lakes by one half within about five years by ecologically favourable

[11] One example is annex 40 of the German waste water administrative regulation issued in 1989 which required the galvanic industry to avoid any EDTA release into waste water. In 1992, corresponding EDTA emissions had been reduced by one half.

[12] Water utility groups and LAWA did not sign the document because it did not have the status of a formal governmental regulation.

substitutes and by the development and use of appropriate technologies to avoid and to reduce EDTA in waste waters, and to document and control progress by regular measurements in surface waters.

After this pragmatic flexible strategy of a medium term 50% EDTA reduction until 1996 had been consensually adopted leaving (sufficient) latitude for case-specific interpretation according to the interests of actors involved, the subscribing participants of the EDTA discourse felt bound to the declaration even if they doubted later if they would sign it once more. As a consequence, they tried to do their best to contribute to the declaration's objectives and correlated tasks as long as these efforts were in relative harmony with their genuine interests.

The number of participants in the continuing annual EDTA meetings doubled from more than 20 in the early 1990s to close to 50 in the late 1990s. This reflected the broadening problem recognition by and the inclusion of various political, industrial and R&D organisations important for the practical realisation of the declaration, for instance state ministries, water utility groups, research institutes, and industrial associations representing EDTA users.

3.1.2 Efforts and problems to implement the EDTA declaration

After 1992 these EDTA meetings were organised by UBA because of a considerable reduction of corresponding personnel in the BMU, on the one hand, and because delegation of this duty by the BMU to the technically more competent UBA personnel appeared convenient for organising the technical implementation of the declaration. The corresponding activities undertaken and problems to be discussed during the 1990s can be enumerated as follows:

1. Empirical information had to be gathered about
   - the pattern of EDTA amounts applied for different purposes, of (local) EDTA emissions into surface waters, of EDTA concentration and degradation in surface waters, and of EDTA concentrations in drinking water;
   - the significance of EDTA volumes imported and exported by transportation in rivers;
   - environmental and health impact studies of EDTA;
   - and varying national and EU attitudes, strategies and regulations vis-à-vis EDTA.

   Furthermore, the validity of the data collected had to be assessed. These activities contributed to recognising the actual complexity of the EDTA issue and the at first forgotten significance of EDTA users when realising EDTA reduction strategies.

2. The problem of variable data was particularly significant for the EDTA measurement programs in surface waters, because their results depended on measurement techniques as well as on the frequency of samples taken that varied according to the differing parameters and criteria of the overall measurement programs on water quality pursued by German states, within which EDTA concentrations were

determined.[13] Depending on measurement technique and reference material chosen, measurement results of concentrations of chelating agents in waste water may well vary up to a factor of 10.[14] Variations in EDTA measurements led to continuous irritation, debate on appropriate measuring procedures, and a need for their explanation in the annual EDTA meetings. Even at the EDTA meeting in 2000 contradictory data, indicating about 25% or about 50% overall reduction in EDTA loads or concentrations in German surface waters from 1991/92 to 1999, were presented without their proponents being able to give unequivocally clear (methodical) reasons for these discrepancies in spite of their political significance.[15] Nevertheless, when the degree of achieved reduction of EDTA loads in surface waters had to be assessed in the late 1990s according to the EDTA declaration, there was substantiated consensus that the data indicating ca. 30% reduction were reliable and valid ones.

3. Often agreed upon in the EDTA meetings, various (participating) institutions prepared papers presenting the results of their inquiries partly moulded by their position on EDTA as indicated above in this section. In such cases the position papers were countered by papers of other organisations with opposing interests, such as the VCI questioning the legitimacy of UBA recommendations. These papers can be interpreted as the main part of the ongoing process of appropriate problem definition and negotiating EDTA-related action strategies.

4. Concerning the various EDTA reduction activities, many case-specific organisational and financing decisions had to be taken by public and private institutions. Of particular interest for this case study are decisions about the size and distribution of R&D funds. Interestingly, because no ban on EDTA was strived for by (environmental) policy, which would require sufficient scientific justification of inherent environmental or health risks and/or of suitable substitutes of EDTA, the majority of R&D funding of up to approximately 100 million Euro, most of which addressed the development of EDTA substitutes, came from industrial corporations primarily for inhouse, but also for external projects. Some funding came from (industrial) foundations, too. After having still spent considerable funds for R&D projects on NTA during the 1980s within the context of the phosphate limiting ordinance ETP spent some resources (around 0,5 million Euro) on intentional biodegradation of EDTA, funded by the BMBF, and on properties, production, application and emission quantities of 18 different chelating agents, funded by UBA since 1999.[16]

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[13] Therefore, the demand to change costly water quality measurement programs in order to harmonize EDTA measurement techniques could not claim high legitimacy. In addition, however, participation of some states in or some measurement spots of EDTA measurement programs were suspended because of scarce financial resources.

[14] Meanwhile the ESWE institute has submitted a measurement technique based on ^{13}C-isotope-labelled reference material to be accepted as official standard procedure to reliably determine concentrations of chelating agents.

[15] However, for instance a study elaborating systematic procedures towards a comprehensive balance of emissions of EDTA and other slowly degradable chelating agents has been commissioned by the environmental agency of the state Baden-Württemberg in 2000.

[16] First research results, presented by the commissioned ESWE institute at the 14. EDTA meeting, clearly distinguished between different chemical groups of chelating agents, criticised the unavailability

5. Research projects besides genuine R&D efforts to reduce EDTA loads in water bodies refer to measuring EDTA concentrations, to inquiring features of EDTA sale and use, to investigating environmental, health and labour impacts of EDTA, or to studying similar properties of EDTA substitutes. Funding and performance of this type of studies, not investigated further here in this report, have been typically done more by and in public institutions (e.g. BUA 1996, the above mentioned study funded by UBA, the EU risk assessment on EDTA). In contrast, market oriented R&D on EDTA substitutes or on improving processing technologies typically has been carried out within industries concerned.

6. The option to biologically degrade EDTA in sewage plants has been pursued by several biotechnological set-ups. Because most of them attempted by industry did not work satisfactorily or only under specific atypical conditions (e.g. biodegradation of EDTA in waste water under atypical alkaline conditions of p_H >8,5), the R&D projects of EDTA degradation by micro-organisms pursued by a university research group since 10 years at present do receive further support for scaling-up experiments and industrial application neither by industry nor by public funds. Thus, biodegradation of EDTA by biotechnological set-ups currently is not pursued as a major practical option except for specific purposes.

7. A lot of substitutes and also alternative processing technologies concerning EDTA use have been developed and introduced in the market by different companies, both for broad range application and for specific purposes. The main results of these efforts and accompanying learning processes were that a substitute with similar favourable properties offered by EDTA could not be found, that different substitutes for different conditions and objectives had to be developed, that one major task was to find the right balance between efficacy and biodegradability of chelating agents, that higher production costs of substitutes, especially when combined with lower than EDTA efficacy, worked as a strong barrier to market acceptance due to the market power of EDTA users, and that the recognition of EDTA as an environmental problem and the timing of testing and installing new technological arrangements were crucial for the willingness of EDTA users to change their manufacturing or cleaning systems accordingly. Altogether, well biodegradable substitutes such as citrate or tartrate were no effective alternatives, substitutes such as PDTA, or enzymatic membrane cleaning systems often were applicable for specialised purposes only (bleach-fix baths, whey-processing), substitutes such as DTPA (pulp and paper) or NTA (detergents) are frequently used but critically evaluated concerning potential environmental or health risks, and medium-strong chelating agents such as MGDA, IDS, or EDDS have - with the backing of large chemical companies - reasonable market chances, though still for limited application areas only.

8. BASF as the main producer and also an important user of EDTA in Germany took considerable efforts within a general program of minimizing emissions in the late 1980s and early 1990s to reduce EDTA release in waste water by systematic

of crucial data, and recommended the development of standardized methods of analysis.

optimisation of EDTA production processes, by integrating processing technology arrangements of various production processes in closed cycles, by reprocessing EDTA containing wastes, by substituting EDTA in quite a few production schemes, and by developing and testing various substitutes with only MGDA left at present, whereas NTA and DTPA had already been produced in the 1980s, too. BASF thus reduced EDTA release from 670 tons in 1986 to 138 tons in 1991 and to about 38 tons in 1997, 1998 and 1999, respectively. Now an emission level has been reached where further reductions require unproportional investments, even if an emission reduction strategy corresponds to the strategic orientation of BASF to sell EDTA to customers instead of releasing it into wastewater.

9. These studies and R&D projects, and corresponding EDTA meetings and debates strongly contributed to generating a more complex and differentiated knowledge and problem perspective on the EDTA issue among many participants of the EDTA discourse, and can thus be interpreted as important social learning process. It helped to recognise uncertainties and still new EDTA-related problems, such as unknown environmental impacts of EDTA metabolites, and to widen the problem horizon of the debate on EDTA towards a comparison of the benefits and environmental costs of chelating agents in general, and towards an emphasis on problems instead on technology or a substance, when asking for the need, benefits, and risks of a specific chelating agent.

10. A crucial task in approaching the 50% EDTA reduction objective was the control of factual reduction figures in EDTA use and load as pointed out above. Partly, the information gathering and measurement programs listed above followed this task. Furthermore, EP institutions, especially UBA, realised the limited validity of (soft) figures on (reduced) EDTA use provided by industrial associations because of their interest in presenting favourable figures, and because these depended on incomplete and voluntary informations by subsidiary associations (e.g. TEGEWA or IHO informing VCI) or by corporate members (e.g. informing TEGEWA or IHO). As a consequence UBA approached industrial sectors and companies applying EDTA more directly in order to thereby induce awareness and reduction of EDTA emissions. Finally, this task implied detecting and closing loopholes in environmental regulations utilised by companies to circumvent prescriptions requiring prevention of EDTA emission.

    For instance, annex 53 to the waste water administrative regulation applying § 7a of the federal water act (WHG), concerning waste water discharges of the photographic industry, first issued in 1993, required zero discharge of waste water stemming from the *treatment* of bleaching and bleach-fix baths. As long as photo laboratories could claim, however, not to have treated these baths, they were legally not forced to avoid EDTA wastewater discharges in spite of the corresponding intention of annex 53.

11. Following the "discovery" of EDTA users UBA took efforts to approach specific user groups, to gain information about their EDTA application patterns, to convince them to reduce EDTA use or release, and to jointly formulate leaflets raising their

awareness of the environmental relevance and reduction potentials of EDTA.[17,18] After having recognised the EDTA issue and being somehow convinced to support reduction objectives the corresponding industry sector associations such as IHO or TEGEWA undertook efforts to draw attention to the EDTA topic and to induce action to reduce EDTA release among their members mainly by information dissemination and persuasion because they only dispose of persuasive instruments vis-à-vis their members. Parallel to this growing awareness EDTA users and customers of EDTA containing products exerted some pressure on EDTA suppliers to avoid this ingredient in their products. Thus, environmental policy, persuasive action of industrial associations and market pull worked together to effect reduction in EDTA use.

12. However, because the rearrangement of industrial processes and machinery typically is an expensive step, and because in most cases neither the environmental risks known nor existing environmental regulations urged (small and medium sized) companies to replace EDTA by possibly doubtful substitutes such as NTA, such rearrangements to reduce or to avoid EDTA use and release tended to happen only under favourable circumstances, i.e. in case of machinery replacement intended anyhow and/or if they promised to show quick results, did not require long and extensive testing periods, and did not affect efficacy. As a consequence, transition periods of reducing or phasing out EDTA use tend to last considerably longer than the 5 years originally expected in the EDTA declaration.

13. Because the implementation of formal agreements and regulations typically has to occur on site, local water authorities - interacting with local companies - may well play a decisive role in realising EDTA reduction goals. As mainly the German states have jurisdiction of water regulation, local water authorities have considerable margin of interpreting federal rules, particularly if they are non-binding declarations propagated by UBA. Therefore, on the one hand, companies might in some cases, depending on the rigor of administrative instructions by local water authorities, well feel subordinated to undue requirements beyond the spirit of the EDTA declaration. On the other hand, however, with a soft formulation denominating the obligation to reduce the pollutant load after having examined reasonable possibilities individually, local water authorities have little chance to interpret such a rule extensively, if the company concerned claims the economic unviability of strong EDTA reduction requirements or even threatens to close down the plant.[19] Thus, interpretation and action favourable for EDTA reduction on the local level was and is dependent on corresponding attitudes of (local) actors involved and on accompanying socioeconomic (market) pressure.

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[17] Already for the beverage sector, for instance, quite some different user groups had to be addressed: milk industry, fruit juice producers, mineral water producers, breweries, wine growers.

[18] Significantly, the European amino-carboxylates producers committee, a sector group of CEFIC, distributed a leaflet countering UBA's one for food industry with hard criticisms.

[19] Thus, corresponding complaints from both sides were advanced by some interviewees.

14. Parallel to ongoing reduction measures in the photochemical industry and after the discovery of loopholes in waste water regulations mentioned above, UBA took considerable efforts to convince this sector to agree on a separate voluntary agreement on additional 30% reduction of EDTA loads until the end of 2000, that results from application in the photographic industry. After long negotiations concerning mainly its phrasing such a voluntary agreement was signed in January 1998 by the heads of the associations of the photochemical industry, of wholesale photo laboratories, and of professional photo laboratories. Including producers and users of photochemicals, the former ones committed themselves to rearrange their bleaching and bleach-fix baths in order to reduce their content of not readily biodegradable chelating agents in general by 50% relative to 1995. The latter ones bound themselves to use the new baths after one year of market introduction or to take equivalent means to reduce not readily biodegradable chelating agents accordingly, and to deliver their photo baths only to those waste management companies whose processing facilities are not expected to release not readily biodegradable chelating agents into surface waters. And the photographic industry committed itself to undertake appropriate marketing efforts for the new photo baths, to provide information about biodegradability and eco-toxicity of EDTA substitutes developed and about their amounts used and released, and to identify concentrations and loads of chelating agents used in at least three representative large photo laboratories in 1997, 1999 and 2001. As it looks like at present, the photographic industry will fulfill its voluntary obligation with some time delay in 2001. The main reason for the continuous efforts of the photographic industry to reduce EDTA use by applying more expensive substitutes was the perceived long term cost impact resulting from the negative image of an environmental polluter by being a member of polluting chemical industries.

15. When gathering and evaluating information about EDTA use and release in different sectors and rivers, it became evident that the goal of the EDTA declaration to halve EDTA loads in surface waters after around 5 years would not be reached, although reductions of EDTA release were certainly observed in Germany, contrary to some other EU countries.[20] Therefore the EDTA declaration was supplemented to prolongate it in order to reach the 50% reduction goal till the end of 2001 and to avoid EDTA substitution by other not readily biodegradable chelating agents. This amendment was discussed in 1998 and signed by the same and three other institutions (photochemical industry association, IHO, TEGEWA), whereas the LAWA continues its support by water measurements without signing, and associations of food industry addressed by UBA support but did not sign the amendment because of little influence and lacking ecoaccounts of EDTA. The BMU finally subscribed to this amendment in September 2000. With the evidence provided at the EDTA meeting in 2000, that EDTA loads in surface waters decreased only about 25% in 1999 compared to 1991/92 and even grew somewhat compared to 1998, it is

[20] This is mainly due to increased EDTA use in the pulp and paper industry substituting chlorine bleaching by peroxide bleaching (see Conrad 2000c).

doubtful again, however, if the 50% reduction goal will be reached in 2001, after it was already missed in 1996.

16. One focus of the EDTA policy game is now at the EU level, where the EDTA risk assessment has been debated with lobby groups trying to influence its conclusions, before it was delivered by UBA as the designated German rapporteur to the EU Commission in 2000, and where so-called BREF notes (best available technology reference notes) relating to the EU-IPPC directive 96/61, addressing integrated pollution prevention and control, influence (national) regulatory policies by identifying appropriate technologies preventing environmental pollution. Again, industry lobbies are intensely collaborating in order to limit BREF impacts on technology requirements.

Altogether reductions in EDTA use and release achieved in 1999 varied considerably according to industrial sector and according to substitutes used, as indicated above in section 2. In view of even rising EDTA use in some other countries and of probably much lower reductions achieved by a command-and-control policy approach most actors involved in the EDTA policy game evaluate positively its evolution, which results from a combination of voluntary declaration, stimulated cooperation and political pressure, in spite of having missed the formal goal of the EDTA declaration. This atmosphere of cooperative policy organisation acknowledging differing interests and objectives of participating actors allowed agreeing on an amendment of the EDTA declaration without serious problems. With a consensus in principle to further reduce EDTA release, consequent and pragmatic action in this direction, including comparative assessments of substituting chelating agents, too, is considered more important than achieving specified reduction targets, at least by the key promoting actors.

Taking into account the limited, scientifically based environmental significance of EDTA and EDTA releases decreasing anyhow in the 1980s, the annual EDTA meetings and the EDTA declaration quite likely induced an eigendynamic[21] of continuous efforts to reduce EDTA use and emission by at least three overlapping mutually reinforcing processes: social learning processes of differentiated understanding and differentiated cognitive framing of the EDTA issue; arguing for and defending one's own interests, however, in a partly cooperative political setting; and commitment to perform agreed-upon tasks by all relevant actors involved.[22] Without this eigendynamic, introduced with the help of environmental policy action, one may well doubt that similar progress in reducing EDTA release could and would have been achieved.

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[21] This term means the (social) dynamics induced by the vested interests, sunk costs, and inertia of a system, institution, or group, once it has become firmly established and developed its own momentum.

[22] More than one interviewee expressed his concern that he and the association of chemical industries he represented actively support the EDTA declaration because of the obligation undertaken although he did not consider it justified for scientifically substantiated environmental reasons.

3.2 Producers, suppliers, users

When investigating environmental innovations, it is important to distinguish between three groups of economic actors, namely producers, suppliers, as defined in footnote 7, and users of EDTA, that may opt for different (technical) solutions toward reducing EDTA release. This distinction is important because company and market structures differ between these groups, because their possible contributions to reducing EDTA release vary, and because the actual (technical and economic) viability of EDTA-related environmental innovations to a large degree depends on a cooperative interplay of these groups. Thus, EDTA users were largely overlooked during the early EDTA discourse. This was recognised as a mistake by its participants when the implementation of the EDTA declaration got on the agenda; and it was not by chance that UBA in turn approached different user groups individually.

EDTA producers typically have been large or medium-sized chemical companies, capable of producing substitutes, too. In Germany, BASF was the only producer, which belonged to the initiating and driving forces of the EDTA meetings and, for reasons indicated above, took considerable efforts to reduce its own EDTA emissions and to develop and introduce EDTA substitutes on the market. Without BASF's engagement in favour of reducing EDTA release the VCI, of which BASF is an important member, would hardly have supported the EDTA declaration. After other producers such as DOW Europe and Akzo Nobel had entered the German market, too, BASF did not sign the amendment of the EDTA declaration as a single company and commissioned TEGEWA as an industry association of EDTA producers and suppliers, of which BASF is a member, in 1998 with the task to represent EDTA producer concerns on the EDTA meetings, though key persons of BASF continued to participate in them as in the past.

EDTA producers can contribute in principle to all three technical options to reduce EDTA release, namely by minimizing EDTA losses in production and waste management processes, by degrading EDTA in waste water treatment plants, and by developing EDTA substitutes. BASF invested in all three options, including financial support of a university project on EDTA biodegradation, which led in the end mainly to company internal process optimisation and to market introduction of MGDA. Other chemical companies developed other EDTA substitutes and even enforced research on biological degradation of EDTA in wastewater treatment plants, too.

EDTA suppliers, that frequently are large or medium sized companies, can also contribute to minimizing EDTA losses by process optimisation when preparing their EDTA containing products such as detergents or by omitting or substituting EDTA in their product formulations. Corresponding examples are replacement of EDTA by PDTA, EDDS, and ADA in photochemical bleaching and bleach-fix baths, avoidance of EDTA in household cleaning products, and the development of EDTA-free detergents for industry. The market success of such development efforts strongly depends on price and a convincing customer relationship because the clients are price sensitive and prepared to change their supplier.

As indicated above, EDTA users belong to many different industrial sectors and, apart from private households, are often small and medium sized companies, who frequently did or do not know that they use EDTA in their products. They can contribute to reducing EDTA release by rearrangements of their facilities in such a manner that these utilise EDTA substitutes, minimize EDTA emissions by process optimisation, or eliminate EDTA by physical, chemical or biological decomposition. The specific technologies and substitutes appropriate for these purposes vary between areas of EDTA use. For example: EDTA is physically eliminated by the handling of the ashes resulting from flue gas desulphurisation in the Buschhaus power plant; DTPA was used instead of EDTA in bleaching processes of the pulp and paper industry; EDTA is avoided or recycled and chemically eliminated in the galvanic industry so that its waste water does not contain EDTA any longer, in compliance with annex 40 of the waste water administrative regulation issued in 1989; EDTA is less used in cleaning products and systems of various beverage industries (breweries, fruit juice, mineral water, milk industries) depending on the specific cleaning purpose (bottles, track lubricants, membranes etc.); and EDTA has been replaced in various arrangements of MILEI, a manufacturer of whey-products, by applying diverse substitutes (NTA, IDS, phosphonates) and an enzyme-based cleaning process.

Altogether these examples indicate that more basic innovations such as substitutes or biodegradation systems of EDTA should be expected to occur in chemical industries and (bio)chemical engineering R&D institutes, i.e. on the producer side, whereas EDTA suppliers and users should take over and implement these (product) innovations by (plant-specific) adaptive rearrangements of their production and waste management installations, which at least partly may well be considered as process innovations.

3.3 Examples of innovation efforts

This section summarizes in somewhat more detail five examples of innovation efforts to reduce or eliminate EDTA release in surface waters, namely biological degradation on a laboratory scale by a university institute of biochemical engineering at Paderborn and since 1995 at Braunschweig, process optimisation and substitute development by BASF, development and market introduction of the substitute IDS by Bayer, development of enzymatic cleaning by Diversey Lever and testing of several cleaning systems by MILEI, and development of EDTA substitutes in the photochemical industry.

3.3.1 EDTA biodegradation by bacteria

As research projects often originate from chance events and ideas, a university scientist who listened to a lecture about EDTA in 1988 questioned the statement of biological non-degradability of EDTA. He found out that there exist phylogenetically related bacteria in quite different world regions, which are capable to degrade EDTA. Apart from interesting questions for basic research the biotechnological potential of this discovery was realised and subsequently investigated within this university institute of biochemical engineering. Three subsequent corresponding R&D projects were funded by the DFG in 1993-97, by the BMFT in 1994-96[23], and by the AIF in 1997-2000. Further (parallel) R&D project proposals addressed to the BMBF in 1997 and, together with the ESWE institute, to the DBU in 1999 were not funded for different contextual reasons. Altogether, several researchers, mainly PhD candidates and students, corresponding 2 and later 3 to 4 fulltime equivalents, worked within these projects spending around 1 million Euro. The projects were scientifically successful, finding out suitable microorganisms and appropriate physico-chemical technologies to biodegrade EDTA, contained in wastewaters, in laboratory experiments (Nörtemann 1999).[24]

According to the calculations of the research group biodegradation of inexpensive and multi-applicable EDTA should therefore be preferred to better degradable, but more expensive and often technically less suited EDTA substitutes. Consequently further attempts have been made to cooperate with EDTA producers or users in installing a pilot or demonstration plant using the EDTA biodegradation technology developed. However, according to past impressions of the research group at least, EDTA producers wanted to sell their (newly) developed EDTA substitutes instead, and EDTA users tended to prefer either continuing operation of existing plants applying EDTA without extra investments in waste water treatment or EDTA substitutes rather than additional EDTA biodegradation, and therefore showed only limited interest in collaborating in a project installing a demonstration plant that biodegrades EDTA. In the critical assessment of this long-lasting university project by outside institutions, however, this biodegradation technology has not yet demonstrated its technical viability at an industrial level or at least in a demonstration plant, and, even if adequately installed, appears to be too complicated for practical purposes of waste water management by small or medium sized companies. Clearly, the university institute has not the resources and marketing capacity of a large chemical company, for instance developing EDTA substitutes, in order to successfully introduce a viable EDTA biodegradation system on the market on its own.

3.3.2 Process optimisation and substitute development by the main producer of EDTA

The various efforts of BASF to reduce (its own) EDTA release have already been indicated above. It is important to note in this context how the framework conditions and BASF's capacity to act crucially influence the viability of the measures undertaken. BASF produces EDTA, uses it in its own plants, too, and emits it into wastewater because of both operations. In order to reduce internal EDTA release BASF successfully undertook considerable efforts mainly by partly substituting internal use of EDTA and by process optimisation technologies embedded in a general program to minimize emissions. These efforts included improved processing technologies, closed cycle arrangements, waste water treatment in a newly built sewage treatment plant, together

[23] This included funding by the BASF, too.

[24] Currently, the research group makes similar attempts to biodegrade DTPA.

costing close to 5 million Euro, resulting in a lot of adaptive innovations concerning processing improvements. No serious efforts to biodegrade EDTA were made. After the EDTA declaration in 1991 primarily EDTA release due to its internal use was reduced, while EDTA release due to its production was already reduced significantly before.

Once processing technology optimisation had started, its eigendynamic led to continuous reduction efforts in spite of their increasing costs. Apart from this social eigendynamic three main strategic orientations of BASF worked together in favour of reducing EDTA emissions: recognition of the likely (economic) impact of a loss of the chemical industry's credibility without effective implementation of environmental management within the corporation; recognition of continuously rising costs of waste treatment and disposal in general; and reliance on the development and marketing of EDTA substitutes due to the essential technical need for chelating agents.

Thus, the option of EDTA substitution was strongly pursued by BASF, too, within an R&D program to screen appropriate biologically degradable chelating agents[25] although several newly developed and registered substitutes such as ISDA did not survive on the market. In Germany, BASF is the chief producer of many substitutes such as NTA, MGDA, DTPA, or PDTA.[26] R&D investments in EDTA substitutes amounted to at least around 20 million Euro over the last 20 years. Apart from the already well established substitutes NTA and DTPA, the newly developed substitute MGDA, a medium-strong chelating agent suitable mainly for cleaning purposes has meanwhile started penetrating the market quite slowly with sales of still less than 1 ton annually because of comparatively high production costs and limited willingness of customers to pay higher prices.

Clearly, the R&D as well as the marketing capacity of BASF together with the just listed framework conditions in favour of waste minimization (demand for environmental management, rising waste treatment and disposal costs, existence of and demand for EDTA substitutes) make plausible the considerable R&D efforts of BASF and the actual realisation of their results by BASF to reduce EDTA release. It has to be recognised, however, that BASF’s main reduction strategy aimed at cutting down internal EDTA losses and not at lowering EDTA sales figures by changing customers’ preferences in favour of EDTA substitutes.

3.3.3 Development of the substitute IDS

IDS is another EDTA substitute for which its producer Bayer sees a high market potential. IDS is a medium-strong complexing agent that can replace EDTA in many cases where medium-strong chelating agents suffice to achieve the objective to mask disturbing metal ions. IDS is biodegradable and has no serious negative environmental

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[25] Frequently promising substances are not developed further because they require new processing technology installations and therefore cannot be produced economically on a large technical scale.

[26] For understandable technical reasons, these substitutes relate to the H-C-N basis of the production process profile of BASF. Thus, another substitute IDS, addressed below, would hardly have been developed by BASF because it did not fit this profile.

impacts; its toxicological, ecotoxicological and mutagenic effects are minimal according to present tests. Therefore, IDS has properties superior to other EDTA substitutes such as NTA, the use of which is not recommended or even restricted to special applications in several countries because of its potential carcinogenic impacts.

Like the previous BASF example, essentially the situational combination of structural driving forces, namely the economic pressure to process a basic chemical, the favourable analysis of market chances of alternative new complexing and dispersing agents, and existing corporate capacities, was decisive for the successful development of IDS. Because Bayer is no producer of EDTA, there was no relevant environmental concern and political pressure to reduce EDTA release affecting Bayer, but only the market opportunity to develop an economically profitable EDTA substitute.

In two large plants in the USA lots of maleic acid anhydride (MSA) are produced as a basic chemical primarily used as softening agent. In view of low and fluctuating market prices it appeared reasonable for Bayer to process this basic chemical inhouse into marketable fine chemicals, and thereby to become independent from the business cycles of this basic chemical. The relating production of complexing and dispersing agents seemed to offer a promising option because they have a variety of application areas. The market analysis looked for deficiencies of chelating agents already sold on the market and for the potential interest of customers to change their formulations or technical installations depending on rearrangement costs and/or savings due to such rearrangements. Typically rearrangements in the production and use of detergents tend to require comparatively low investments.

Because of the competitive advantage resulting from time savings and burden sharing of development costs the development of new fine chemicals frequently is arranged by sequential agreements, where the customers, being themselves large corporations experiment with and develop the technical installations and processes apt for the new chemical developed by its producer.[27] Within such a sequential agreement underlying the development of IDS and PASP as new complexing and dispersing agents the cooperating partners allow mutual insight in laboratory documents and promote know-how transfer. In this case, R&D costs amounted to around 25 million Euro between 1992 and 1997 for Bayer alone, with about 12 persons from research, technical engineering and marketing involved. The customer participating in this sequential agreement invested its resources somewhat later. Success of such pilot projects is crucial, first because the customer participating in the R&D project reflects upon other marketable options of the new chemical, too, which would reduce its logistic expenses and enlarge the sales potential of its producer such as Bayer. Second, the proof of the suitability of the new chemical by one eminent customer generates a domino effect of rising demand that first of all allows profitable production of IDS and PASP. Both substantial and adjustment innovations were necessary on the producer and the supplier side for the development and application of these new chemicals. Compared to

[27] Because these customers, trading with products containing new chemicals, typically are closer to the end user and are exposed to corresponding market competition, their R&D time horizon and testing arrangements tend to be oriented much more short term than Bayer's longer term planning horizon.

usual time spans of 10 to 15 years, and taking into consideration the many technical problems associated with upscaling production plants, development and market introduction of both new chemicals have to be considered as quite rapid and efficient ones, apart from some considerable difficulties concerning patenting which had to be solved. Although being different types of chemicals, IDS and PASP may well partly compete one with each other for similar detergent purposes.

Furthermore, in parallel with growing production and sales volumes extensive toxicological and ecotoxicological studies lasting about three years and costing more than half a million Euro are required for the registration of each substance, and are still to be completed for higher production levels. IDS was licensed for sale in Europe and in the USA in early 1998. In this case, registration in Germany implies registration on the EU level.[28] Since 1999 IDS (and PASP) are successfully sold in growing amounts, after extensive marketing efforts in 1998 to convince potential customers of the advantages of the new chemical (see Bayer 1999a, 1999b), although it appears to be still too early to definitely assess market success of IDS. Production capacity will be increased from 2000 onwards. Despite its focus on the promising market of detergents, IDS can well be used for other purposes, too, for instance in cosmetics, though not in the photochemical or semiconductor industry.

Summing up the decisive role of market conditions and chances for IDS development, it appears reasonable to conclude, that Bayer, according to its own view, was only willing to make these considerable investments - apart from the stimulus to process maleic acid anhydride into fine chemicals - because it perceived a good chance for a new chelating agent on the global market. In case of an already existing "ideal-type" complexing agent and without the environmental problems of EDTA and other complexing agents discussed in one way or another in many Western countries[29], Bayer would not have invested in this R&D project. This kind of R&D investment could only be justified economically from a global market perspective, referring to OECD countries in particular. From this perspective the German EDTA debate was a major ingredient, but not of decisive importance for Bayer's corporate strategy.

3.3.4 Avoiding EDTA application in whey processing

The story of testing enzyme-based cleaning of the installations of the company MILEI, which processes whey into protein reach milk products (e.g. yoghurts, fresh cheese, baby food) and exports about two thirds of them as one of few special whey producers in Western Europe with a turnover of ca. 50 million Euro, illustrates both the importance of organisational arrangements and strategic orientations as well as the significance of specific technical settings and objectives for the technical and economic viability of an environmental innovation.

[28] This does not hold true in the case of eco-efficient fertilizers, described in Conrad 2000b.

[29] In the USA, for instance, the environmental impacts of EDTA or NTA are dealt with in a more dispassionate pragmatic attitude, though corresponding research results and international debate are well observed.

Releasing about 60 tons EDTA in waste water annually, MILEI was the sole major emitter on site and therefore was willing to reduce and to avoid EDTA use in time, because it was urged by UBA in this respect, was afraid of continuous public criticism, and expected a legal ban on EDTA use. Between 1997 and 2000 MILEI pursued various projects to do so without public funding even though this was promised to it. Cleaning the whey processing facilities, that is required daily according to the German food act, is a rather complex multi-step process of dissolving organic and inorganic components, which stick to different parts of the whey processing plant, by surface active agents, acid and alkaline baths, and chelating agents, lasting about 4 hours. In particular, cleaning of the ultrafiltration membranes used to percolate whey proteins is difficult because of the risk to destruct them when dissolving adsorbing materials. The various EDTA reduction projects undertaken by MILEI are summarized subsequently.

1. In early 1997 MILEI reduced EDTA applied in the cleaning process and added soda lye to the detergent in order to reduce EDTA release by 30%.
2. MILEI tried NTA as a substitute in April 1997 reducing EDTA use by 50%. This attempt was abandoned because of insufficient cleaning results leading to a decrease in the microbiological quality of products.
3. In parallel, the EDTA containing cleansing solution was separated into a storage tank and concentrated by nanofiltration for subsequent waste disposal or reprocessing. Corresponding tests in a pilot plant proved to be unsatisfactory so that this approach was not continued further.
4. After initial consultation with the above mentioned university institute at Braunschweig, EDTA release was reduced by biological degradation in a pilot plant in 1997, which was built by IMD Micon, presumably a joint subsidiary of DiverseyLever and Akzo Nobel. The technical results of this experiment were reasonable, but MILEI did not pursue this option further because of the considerable additional costs of a subsequent degradation process, which does not avoid EDTA application itself.
5. Still in 1997, MILEI considered to use MGDA as a complete substitute of EDTA in case other options would fail, but did not yet enter in serious testing experiments.
6. An enzyme-based procedure with changes in detergents, formulation, and processing technology developed by DiverseyLever, a subsidiary of Unilever, was tried in the main plant for 1,5 years in 1998/99, which substituted chlorine for dissolving organic materials and permitted to substitute EDTA by IDS for dissolving inorganic materials. However, because of supposedly too effective cleaning impeding the formation of the secondary membrane coating layer needed for protein filtration, which still reoccurred after replacing the membranes by new ones, MILEI did not pursue this option further for about half a year.
7. In 1999 MILEI replaced it by a similar enzyme-based procedure combined with phosphonates as chelating agents, developed by Henkel Ecolab, after having tested this alternative procedure in a pilot plant in 1998 already. Again, in this (ongoing) experiment, EDTA was no longer used. However, the particular well known difficulties with removing calcium compounds, primarily calcium phosphate, again led to bacterial contamination, reduced cleaning performance, and thereby lowered

production performance in continuous operation. Therefore MILEI now pursues a strategy to insert an EDTA-based cleaning step a few times a month in addition to the daily enzyme-based procedure, where it uses both systems provided by DiverseyLever and Henkel Ecolab in each half of its installations in order to avoid dependency from only one supplier.

Altogether, MILEI spent close to 50.000 Euro, particularly for the nanofiltration plant, and a lot of manpower for testing the various options was needed, too, implying additional personnel costs. The investment costs of the different (pilot) projects were borne by their respective suppliers that could see them as necessary testing facilities and as marketing costs because they were interested in selling the corresponding detergents to MILEI and other potential customers on a permanent basis.

Looking at one of these projects from the supplier perspective, one should note that DiverseyLever at first was less ready to invest in enzyme-based cleaning systems than its competitor Henkel Ecolab[30] because of publicly associated health risks. Then the corresponding R&D project was performed within just about half a year as a fast response to competitive pressure urged by the customers, and as a medium term R&D strategy of Unilever to realise potential market options in enzyme-based chemistry. A major task in this respect is the coordination and mutual fit of these two R&D strategies pursued in Unilever's international research centers and in national research units. They mainly lead to less expensive application oriented innovations (in this case about 0,5 million Euro) which can be implemented rapidly, whereas the more long term and more broadly oriented R&D of enzymatic systems may lead to more basic innovations but requires much higher investments, too. Once started, such R&D projects generate a company-internal eigendynamic, depending on the engagement of their promoters, a clear perspective on the problem addressed and its solution, and effective internal communication. Typically, these innovations are optimising processes of a cleaning system as a whole and do not just imply the screening and testing of an enzyme. A well-functioning interplay of development, marketing and sales units is crucial for the success of these innovations, because the "truth" of the superiority of a new product strongly depends on its price and its presentation by sales representatives.

Concerning successful implementation of new cleaning systems, the market power of its customers via changing the supplier prevents high profit margins, on the one hand, and large investments in new technical installations, apart from anyway pending replacements, on the other hand. Furthermore, users want to see quick results of newly installed systems and are therefore badly prepared for long lasting precise testing experiments and possible costly system improvements. Finally, viable innovative arrangements may not work in other settings. Because of the peculiar raw material whey of MILEI its cleaning arrangements cannot be simply utilised in other factories of the milk industry. Thus, technically well viable innovations such as enzyme-based

[30] Henkel engaged in enzyme-based systems earlier in the USA and was interested in exporting them into EU countries and, for this purpose, pursued a clever combined R&D and marketing strategy.

cleaning procedures may have severe difficulties to succeed on the market, as demonstrated by the MILEI example.

3.3.5 Reduction of EDTA release in the photographic industry

Since the 1990s the photographic industry has already been testing and using the EDTA substitutes PDTA and ADA in bleach baths. PDTA, which is produced by for instance Akzo Nobel and BASF in Europe, is only needed in photochemical baths about half the amount of EDTA needed, but is more expensive than EDTA. One reason for this is the small production volume of PDTA. It is also not readily biodegradable and is intended to be applied to bleach baths. These bleach baths contain about 15% of all complexing agents in photographic laboratories.

ADA is a medium-strong complexing agent developed by Agfa, a former subsidiary of Bayer, and is used by Agfa-supplied laboratories in bleaching solutions. But users had to pay more and were confronted with problems of technical quality such as germ formation. ADA is developed further so that its use in bleach-fix baths can be expected, too, increasing its up till now low acceptance on the market.

All the big companies, such as Agfa, Fuji and Kodak, are global players on the photochemical market.[31] For understandable economic reasons they try to create a product that will be useful worldwide or at least European-wide and not only in Germany. As a consequence, German subsidiaries understandably had problems to convince their (Japanese or American) headquarters Fuji or Kodak to make investments in developing substitutes for reducing EDTA release, favourable just for the German and, possibly, the Swedish market.

The German market for photographic films and photochemical baths is characterized by fierce competition. Therefore there are economic problems in developing photochemical baths with new easy-degradable complexing agents. To develop EDTA substitutes only for the German market is very expensive. A decision on one basic chemical would have favoured one company over the others, because this company already had the chance to improve its product line on this substance in the past,[32] especially after Agfa had decided to follow its own product line with ADA. Therefore there was little interest in joint development efforts towards photochemical baths with new better biodegradable complexing agents to fulfill the voluntary agreement of the photographic industry, although an agreement on one basic chemical would have saved development costs for all companies.

There are three biodegradable EDTA substitutes for the development of film negatives and photo prints in bleach baths on the market, which have been developed by Agfa, Fuji and Kodak.[33]

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[31] Only Tetenal remained as a relevant German supplier of photochemical baths for mini-laboratories.

[32] Just four firms own most of the about 60 wholesale photographic laboratories in Germany, with Fuji providing about two thirds of all photochemical baths for two of these firms.

[33] Meanwhile these EDTA substitutes are partly used in wholesale laboratories, though not yet replacing EDTA in all types of photographic processing. The resulting different, somewhat more expensive

Agfa developed the EDTA substitute ADA and is making field tests with bleach-fix baths now. After Associated Octel had in principle developed the EDTA substitute EDDS over about the past 10 years, Fuji, Kodak and Konica put a lot of effort into its further development in order to adapt it to their various specific formulations of bleach-fix baths.[34] The corresponding R&D costs arise in the central research laboratories of the large photographic companies, which are mainly not in Germany. These costs amount to around half a million Euro, including (future) registration costs of about 150.000 Euro because the ferric complex of EDDS is a new chemical. These figures do not include the major R&D costs of Associated Octel, who is the sole producer of EDDS till now. The R&D costs for EDDS are very high compared to the annual sales of EDDS to photographic laboratories in Germany, amounting to about 1,5 million Euro.

EDDS is an isomer of EDTA and a well biodegradable complexing agent with low toxicity. Therefore it seems to be an appropriate substitute for EDTA with many areas of application, but it is much more expensive. Because there is little margin for a price increase of photochemical baths for photofinishers, the sole use of EDDS in bleach-fix baths would be very expensive. Therefore only mixtures containing EDTA and EDDS currently appear to be marketable in order to fulfill the voluntary self-obligation of the photographic industry.[35]

Thus, today many efforts are put into the improvement of already existing formulations and processing technologies, including waste management options of evaporation, burning or resale of recovered photochemical baths for further use.[36] Wastewater treatment can be done by precipitating heavy metals. The ammonia containing rest can be sold to the cement industry for the application in flue gas scrubbers for denitrification.[37] In contrast to these waste management options, developing and testing substitutes is one essential, but only one option to reduce environmental pollution.

As environmental criticism can have a negative influence on the image of the photographic industry, it follows a general direction to avoid that already for economic reasons. Therefore there is a genuine interest of the photographic industry to agree on one EDTA substitute. Such a consensus, however, requires at least the following three preconditions: agreement on one qualified substance; solution of the patent-law problem and of know-how transfer; and limited purchase price of the EDTA substitute for the sole producer.

Apart from the development of EDTA substitutes, Agfa and Gretag, a Swiss manufacturer of photo laboratory installations, offer new types of paper processors, which save a lot of water (90%), energy, chemicals and space. Although the substitution of

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bleach baths are mutually compatible so that a photographic laboratory can change its bath without problems.

[34] Major emphasis is put on EDDS because several corporations are involved in its development and case-specific application and hold respective patents, whereas development of ADA is essentially pursued by Agfa.

[35] Market introduction of EDDS-containing formulations for photochemical baths is expected in late 2000.

[36] Therefore corresponding innovations again are mainly due to optimisation processes.

[37] This waste management strategy of photochemical baths supplanted burning or evaporation strategies during the last two years because it is now cheaper, too.

existing equipment by this new machinery will last quite some years in spite of the high savings implied, wholesale photographic laboratories in this case have no reason to substitute EDTA by much more expensive EDDS for environmental reasons. Another possibility to reduce EDTA release would be a closed photographic processing system with a low EDTA carry-over that already permits compliance with the voluntary self-obligation of the photographic industry. As a consequence, the (economic) viability as well as the (relative) environmental favourability of the EDTA substitutes EDDS or ADA in bleach-fix baths of the photographic industry still remain an open question.

The currently ongoing market penetration of digital photography and computer-generated pictures may have even more profound consequences in case of replacing photochemical processing by direct printout that is associated with quite different environmental impacts to be dealt with in the future.

4 Actors and networks

The actors involved in the case investigated can be defined at two levels: organisations and individuals. Because the various individuals in principle acted according to the rules and interests of their organisational units, it appears sufficient to analyse actor behaviour and constellation at the level of organisational units, although this does not deny the key role of certain individuals for the specific development path of the case history, for example the ministerial director of the BMU organising and phrasing the EDTA declaration. Because the various bargaining and innovation processes are reconstructed at a summary level only and not in substantive detail, it is usually satisfactory to conceive of macro-organisations such as BASF, BMU or UBA as essential actors, although typically organisational sub-units within a macro-organisation such as the R&D or marketing department or the responsible administrative unit are the true organisational actors with on average 5 to 15 individuals belonging to this unit.

4.1 Differing actor interests, perceptions, and strategies

Because of the manifold areas of EDTA application the related overall actor constellation, largely reflected in the annual EDTA meetings, is likely to be a situational and temporary one, where many special (loose) networks overlap and the actors have only occasional contact if they do not belong to the same area, for instance to the photographic industry. As a consequence, overall EDTA reduction and substitution, as a goal agreed upon by most actors later on and as the focal point of this case study, result from the relating (mutually interacting) activities of many actors in different networks, but cannot be controlled by one or few key actors. For well-defined specific sectors joint strategic action is feasible though only to a limited degree, as illustrated by the differing interests and perceptions of EDTA producers, suppliers, and users.

The actors involved in (or concerned by) EDTA reduction strategies can be divided into the following groups: federal politico-administrative actors, namely BMU, BMFT/BMBF, BMG, BMWi, LAWA, UBA, BgVV, BUA, and PTWT, state and local water authorities, EU (Commission) bodies, water utilities and their industrial associations (BGW, DVGW) and research units (e.g. TZW, ESWE), (academic) water and chemistry related research institutes (e.g. at the TU Braunschweig), producers of EDTA and its substitutes, particularly BASF, Bayer, and Akzo Nobel, and their industrial associations, EDTA formulators/suppliers, such as DiverseyLever, Henkel Ecolab, Agfa, Fuji, and Kodak, and their industrial associations, EDTA users belonging to many different industry sectors, for example detergents and cleaning products, photo, textiles, pulp and paper, metal treatment, or galvanic breweries, food, beverage, chemicals, cosmetics, and pharmaceuticals.

As described above, key actors in EDTA discourse and policy making were the BMU, UBA, water utility groups (ARW, AWWR) and associations (BGW, DVGW), BASF, VCI, and industry sector associations (e.g. photochemical industry, IHO) who were of decisive importance for defining, organising and monitoring EDTA reduction arrangements.

In general, all actors largely acted according to their interest, problem perception and strategic orientation, frequently combining a clever use of existing economic and political framework conditions (e.g. window of opportunity for EDTA substitutes, improbability of an EDTA ban, interpretation of environmental regulations), the willingness to come to and to cooperate in voluntary agreements considered acceptable and viable, and the commitment to fulfill such an agreement, once signed, inducing a quite remarkable eigendynamic. In this context, the following superimposing features can explain the actual reduction of EDTA release achieved:

1. Despite quite differing interests, problem perceptions and strategic orientations of the various actors there was still some common core knowledge and problem perspective allowing for compromising declarations and agreements.[38]
2. Certainly, actor interests partly were in opposition to each other, but could be reconciled to some degree without jeopardizing the very basis of their proponents and because of the partially shared view that environmental concern is an at least legitimate social concern.
3. The corresponding overall sociocultural and sociopolitical background of serious environmental concern and the related threat of being (anew) publicly attacked for insufficient environmental protection action, leading to serious undesired economic or political impacts, helped to prepare the ground for committing oneself to EDTA reduction efforts, especially if undertaken by other parties concerned as well.
4. Furthermore, interests and strategies of individual actors tended to be multiple and not uniform ones so that partially they were well in conformity with those of other actors, for instance marketing of newly developed EDTA substitutes by BASF as an EDTA producer and avoidance of EDTA release by environmental policy.
5. The procedural arrangements pursued by environmental policy actors, i.e. EDTA meetings (with agreed upon monitoring duties etc.) and voluntary arrangements, permitted all (participating) actors to stick to their interests, perceptions and

[38] Thus, the validity of the Thomas theorem does not contradict agreement on common general objectives.

strategies, considered as legitimate ones, on the one hand, and induced to some degree a cooperation-oriented social learning process opening up viable paths of EDTA reduction efforts, on the other hand.

6. Once actors had committed themselves, an eigendynamic was created in favour of continuous efforts, and their positive results facilitated to convince other relevant actors, such as EDTA users, to take part in corresponding efforts, too.

These general abstract theses are substantiated by few following examples.

Water utilities were strictly opposed to find anthropogenic, not readily biodegradable substances such as EDTA in surface waters because their elimination in water treatment plants requires additional investments and its appearance in drinking water threatens the image of pure healthy water provided for the population. In their perception EDTA is an at least potentially hazardous substance (e.g. by transporting or remobilising heavy metals). Because a legal ban of EDTA could not be achieved, a strategy to support the EDTA declaration, aspiring to halve EDTA release, to observe and to monitor EDTA concentrations in surface and drinking water, and not to engage rapidly in EDTA elimination technologies in water treatment plants, appears a quite reasonable one for water utilities.

Being in charge of investigating, monitoring and administrating environmental problems and corresponding problem solutions, UBA is interested in contributing practical organisational (and also financial) support in order to reduce and replace EDTA application, because it perceives EDTA as a not readily biodegradable and environmentally potentially hazardous substance. Because according to its view industries typically were not keen on avoiding environmental pollution, environmental policy should try to regulate and control polluting industrial activities as strictly as possible. Therefore emission oriented environmental regulations should be favoured over those aiming at ambient environmental quality control. Consequently, UBA was first opposed to a voluntary EDTA declaration, put considerable emphasis on monitoring activities, approached various EDTA using industries directly in order to convince them to take EDTA reduction measures, and emphasized the use of biodegradable EDTA substitutes, in particular, although their environmental or health impacts might not be sufficiently known, either.

BASF is interested in continuous profitable business without recurrent conflicts with water utilities and without cost inducing bureaucratic environmental regulations. Perceiving EDTA as not particularly ecologically dangerous, but understanding concern of water utilities on this matter, the strategy of BASF appears a quite reasonable one, namely to reduce EDTA release into the Rhine river by an already ongoing waste minimization program, thereby lowering in the long term anyhow rising charges on waste emissions, to better sell produced and recovered EDTA to customers instead to partly release it into waste water, and to replace EDTA by substitutes also produced by BASF.

The IHO represents mainly medium and small sized companies providing cleaning products and detergents for professional use. This sector is a significant formulator for and major supplier of EDTA, though less an emitter of it. The IHO is an actor that became involved in EDTA discourse and politics only since the mid 1990s, when EDTA users were addressed by environmental policy. As a member of the VCI, which had signed the EDTA declaration, the IHO felt obliged to contribute to achieving the declaration's objectives. The IHO had no genuine interest in reducing EDTA use because it did not perceive EDTA as an environmentally dangerous substance; a perception further reinforced by inconsistent propositions of public environmental and health authorities. Once being involved in the EDTA declaration and meetings,[39] the responsible IHO representatives felt committed to their task to persuade its members to substitute EDTA by better biodegradable chelating agents such as NTA in those applications, where the substitution was possible without losing efficacy. Thus, the IHO understandably followed a (mixed) strategy: pointing to the availability of only persuasive instruments when doing its job of achieving reduction of EDTA release by its members; insisting vis-à-vis environmental policy actors on the need to differentiate between areas in which EDTA can be replaced and where it cannot (yet), to strengthen its position as an industrial association by incorporating its members and defending them against outside criticism, and to propagate an image of environmental orientation and environmental management activities of and for its members. Although the IHO has in principle no objection against reducing EDTA release (if technically and economically feasible) and signed the amendment to the EDTA declaration in 2000, it doubts whether activities of this kind are reasonable at the national level at all, not to mention the European context. Thus, it is doubtful in hindsight whether the IHO would join the EDTA declaration once more with the knowledge gained and experiences made so far and without the strong personal engagement of its first representative responsible for managing the EDTA declaration.

4.2 Regulatory, business and knowledge networks

Studying networks around environmental innovations, it is important to (analytically) distinguish regulatory, business and knowledge networks which typically follow different tasks and consist of different actors (van Dijken et al. 1999). In the EDTA case in particular, where the participating actors belong to just one and only occasionally to more than one out of many overlapping loose networks, one can clearly discern the sector-specific differentiation of actor groups concerned with business, with research and development, and with environmental regulation, though they certainly keep themselves informed about and interact with each other. It has been mainly the annual EDTA meetings, which symbolically unite all the various networks by offering a cognitive and organisational frame of common discourse.

Significantly, policy was not strongly involved in funding corresponding R&D projects for reasons indicated above in section 3. Therefore, R&D projects typically were performed within EDTA-related corporations and thus strongly influenced by economic objectives, whereas policy objectives tended to stimulate such projects by the framework

[39] That largely happened without previous careful examination of the likely impacts of this engagement.

conditions set by environmental regulations, the EDTA declaration, and subsequent voluntary agreements, without being involved, however, in their (scientific) details. This kind of direct involvement happened by the cooperation of suppliers and users, or of producers and formulators of chelating agents if both sides contributed to experiments and innovative arrangements to reduce EDTA release. Typically, the research addressing EDTA substitutes was done on a continuous basis in view of (eventual) environmental policy regulations but without straightforward reaction to specific political decisions. This awareness of business concerning possible environmental regulations influences - apart from lobbying efforts in favour of business positions - business strategies, which in turn influence corporate R&D strategies. Similarly, business activities and innovations recognised by policy makers in turn influence policy strategies. But beyond these mutual (indirect) influences, the three types of networks tend to evolve according to their own rules and strategies followed by their affiliated actors, as indicated subsequently.

In the regulatory networks the politico-administrative actors at the federal level such as BMU, UBA, BgVV, LAWA were concerned particularly with

– coordinating various environmental regulations[40] among each other and with other regulations, especially those of health and economic policy,
– advancing as well as harmonizing specific policy strategies preferred by different environmental policy actors (e.g. control of emissions versus control of ambient environmental quality in EDTA policy),
– reconciling federal policy with regulatory activities on the EU, state and local level,
– bargaining with relevant interest groups, mainly from business,
– deciding if certain environmental regulations should be passed or not,
– assessing who has to bear which type of costs resulting from environmental regulations and associated monitoring systems,
– acquiring relevant technical and business information,
– (possibly) commissioning EDTA-related investigations,
– monitoring and controlling EDTA-related activities and emissions,
– getting informed about as well as evaluating and comparing (probable) environmental impacts of alternatives to EDTA application,
– organising relevant communication and agreements via EDTA meetings and working groups,
– and maintaining the overall EDTA reduction strategy pursued.

The other actors in the federal regulatory network have been mainly business corporations and associations, i.e. EDTA producers, suppliers, users, and water utilities, lobbying for their interests, whereas environmental or consumer groups have been at best indirectly involved by generating public debate and criticism with the help of the media.

[40] Apart from the EDTA declaration EDTA is addressed for instance in the following regulations in Germany: ordinances regulating hazardous substances, food additives, water hazard ratings, waste management, waste water with various amendments (BUA 1995:175ff).

At the state and the municipal level environmental ministries and water authorities are the significant politico-administrative actors in the regulatory networks dealing with monitoring, regulating, implementing, negotiating and coordinating activities in confrontation and/or cooperation with corporate economic actors, especially those belonging to the same industrial sectors mentioned above.

Finally, environmental risk assessments and regulations with frequently far reaching long term impacts on national and local regulatory settings are done and issued in regulatory networks at the EU level, where especially industries as well as national and state authorities try to influence administrative bodies of the EU Commission according to their propositions and interests, as illustrated by the EU risk assessment on EDTA or the BREF notes referring to the EU-IPPC directive 96/61 mentioned above.

The business networks concerned with EDTA-related environmental innovations mainly consist of corporate planning, marketing and R&D units including top management which evaluate the chances and costs of certain strategies to reduce or substitute EDTA production or use in view of general corporate strategies and framework conditions, such as availability of competitive options, investments in processing plants, in any case occurring raw materials, (expected) environmental criticism and protest, or an orientation towards responsible care. Corresponding decisions taken in these business networks also imply decisions on the start or stop of an R&D project, and on corporate policy strategies concerning the respective industrial association and environmental policy actors. The business networks may - in case of joint ventures - simply actors from more than one enterprise, but rarely actors from outside the economic sphere.

The knowledge networks are those directly concerned with developing substantial (EDTA-related) environmental innovations. They primarily consist of corporate R&D units and private or public research institutes, possibly supplemented by other cooperating business units (e.g. production, marketing, quality control), responsible research project management bodies funding the project, and competent segments of the professional engineering or scientific community. One should note that only a few of these enumerated actors may constitute an individual knowledge network. As indicated by the innovation efforts described above in section 3.3, cooperation on the R&D level played some role, but rarely more than two or three R&D units were engaged in a specific EDTA-related project. It is largely within the knowledge network that the technical viability of an environmental innovation is decided upon, whereas its economic viability is in the last analysis judged by the business network and the market. Examples described above illustrate these features of knowledge networks, for instance biodegradation of EDTA by bacteria, development of IDS as EDTA substitute, or MILEI's experiments with different options to reduce EDTA use and release.

4.3 The role of environmental policy actors

Looking finally at the role of environmental and technology policy actors in EDTA-related politics and environmental R&D, one may reasonably draw several conclusions. Concerning ETP, the responsible research project management body PTWT was kept informed about EDTA issues and participated in the EDTA meetings, but was not significantly engaged in EDTA politics and R&D, apart from funding one project of the university institute of biochemical engineering described above. Since the BMFT contributed to funding the joint project on NTA in the late 1980s mentioned above, a similar joint project on EDTA was discussed as well, but not funded, mainly because the BMFT saw no reason to co-fund EDTA-related development efforts of industry as long as corresponding regulatory objectives remained unclear and EDTA use or release was not prohibited in general. Whereas till to the EDTA declaration in 1991 the BMU was the key EP actor concerned with environmental regulations addressing EDTA, that preferred for reasons described above an agreement on the voluntary EDTA declaration and successfully launched annual EDTA meetings, since 1992 UBA became the central organising actor concerned with both EP and ETP. By learning the need to carefully differentiate between differing areas of EDTA use implying different technological conditions and ecological impacts, and to weigh the (environmental and economic) pros and cons of EDTA substitutes, UBA gained growing acceptance by industrial actors participating in the EDTA meetings. Pursuing EP objectives, UBA engaged in implementing the EDTA declaration by approaching different EDTA using industries, by monitoring EDTA effluent data, by propagating reasons for and possibilities of reducing EDTA release, and by threatening with formal environmental regulations in case of a lack of corresponding progress. UBA was also the main ETP actor in spite of lacking resources, as it observed and compiled EDTA-related R&D projects, cared for measurement programs of state water authorities and water utilities monitoring EDTA release in surface waters, and offered funding of few R&D projects. Again, neither EDTA-related EP nor ETP were managed by one major actor, and UBA as a key actor without any jurisdiction over federal, state or local authorities could only try to coordinate these policies as far as possible, as indicated in the previous section, but not prevent well occurring inconsistencies between different policies, such as chemical, water, health, and economic policy, or between different (federal, state, municipal) levels of policy making.

5 Innovative solutions to an environmental problem?

In view of the general objective of this case study (see IIUW 1998) this section asks about the ecological quality of EDTA-related environmental innovations, indicates the crucial role of economic factors for their success, and discusses the impact of political action and environmental regulation upon them.

5.1 The crucial significance of cognitive framing

Formally, an environmental innovation is a (fundamental or incremental, technical or social) innovation improving the status of the environment if applied. It is not required that the positive environmental effect is an intentional purpose of the innovative process. However, evaluating the ecological value of an innovation, such as the type and range of environmental improvements, depends on many aspects such as

1. the relative weighting of various, possibly opposing dimensions of environmental protection (e.g. air versus water pollution, substitution versus degradation of a hazardous substance),
2. new (unknown) environmental impacts, particularly those due to physical interaction processes between the innovative product or process and the environment,
3. the social implementability and resulting viability of the (environmental) innovation,
4. its time horizon for substantial environmental improvements to be achieved,
5. its comparison with the status quo ante and with other (competing) environmental innovations,
6. and the overall social strategy (implicitly) preferred to achieve environmental compatibility or even ecological sustainability (e.g. efficiency, sufficiency and consistency strategies; Huber 1995).[41]

Now, if perceptions of and opinions on an innovation differ with respect to these ecological evaluation criteria, disagreement on its ecological value and advantages is most likely. Therefore the cognitive framing of an (environmental) issue plays a crucial role.

As indicated in section 3.1, there was no substantive agreement among the actors involved on the ecological urgency and need to reduce EDTA release into surface waters. Given the admittedly relatively minor environmental and health impacts of EDTA, EDTA-related industries could - independent of existing disagreements on (scientifically investigated) environmental facts - reasonably argue that substitution of EDTA by other better biodegradable, but more expensive chelating agents with partially still unknown environmental impacts was a doubtful strategy to protect the environment.

The various dependencies listed of such an evaluation are illustrated each by one or two examples subsequently, though the impact of cognitive framing on the ecological evaluation of EDTA release and relevant reduction technologies is not elaborated in detail for all the different actors.

Evaluating EDTA as an environmental hazard becomes likely, if one values high its anthropogenic origin and slow biodegradability and is aware of connected risks such as the transportation of chelated heavy metals, the potential remobilisation of heavy metals, synergetic effects with other substances, potential teratogenic and genotoxic

[41] Furthermore, because environmental innovations typically occur in companies, environmental protection is only one out of many innovation goals of a company within its overall innovation processes, within which the weight of environmental protection goals and their complementarity or competition with other innovation goals determine its role and importance. Thus, the more integrated environmental protection measures are, the less can environmental innovations be isolated from 'normal' innovations.

effects, and eventual other unknown impacts, as done by UBA. If on relies, however, on studies indicating the negligibility of those effects under usual conditions, one will not consider EDTA as a real environmental hazard, as stated by EDTA-related industries.

IDS as a suitable and, compared to other biodegradable substitutes, inexpensive medium-strong chelating agent appears to have no serious toxicological, eco-toxicological or other environmental impacts. However, this assessment may still change in case of unsatisfactory results of the main health and environmental impact study that the chemical act requires for further licensing. Similarly, the eventual detection of environmentally dangerous metabolites resulting from biodegradation of chelating agents in surface waters may invalidate their presupposed environmental compatibility, too.[42]

EDDS appears to be a very suitable and environmentally benign substitute of EDTA, especially for photo baths, but it is several times more expensive than EDTA. Because wholesale photo laboratories (and the public as their client) are not willing to pay double or triple prize, at present EDDS is only marketed as a bath mixture together with EDTA.

If the new types of photo processing machinery, that greatly economize use of water, energy and chemicals savings, in addition allow sale of processed waste to the cement industry, which (implicitly) cares for the environmentally sound disposal of EDTA, too, there is little ecological reason to renounce cheap EDTA application in the longer run by gradual replacement of existing machinery in German photo laboratories. Only because of the voluntary agreement of the photographic industry to cut back EDTA release by one more third until 2001, ADA and EDDS are offered as EDTA substitutes on the market now.

The ambiguity of recommendations to substitute EDTA by NTA and the compromise reached between UBA and BgVV, advising to do so without serious increase of NTA application, reflect the trade-off between better biodegradability and potential health risks of NTA.

If EDTA can be biodegraded well and cheaply by bacteria in additional (sophisticated) water treatment plants after use, and if EDTA use can be avoided by environmentally unrisky, but expensive substitutes, and if EDTA can be disposed of by further use of EDTA containing reprocessed wastes in another industry without serious environmental hazards, then no unequivocal answer can be given which option should be preferred on environmental grounds.

Essentially all options followed to reduce EDTA release are technical-fix solutions, which, however, require appropriate social settings, too. As long as one prefers the chemotechnical advantages of applying chelating agents in a modern society, one may only give preference to environmentally less hazardous, though possibly more costly technical-fix solutions for ecological reasons, but there exists no realistic option to renounce them altogether because of their (potential) environmental or health impacts. If one would prefer, however, a less technology based and thus less vulnerable society, one could well imagine of social rearrangements allowing to abandon the use of

[42] This risk was pointed out by detecting oxopiperazine polycarboxylic acids as metabolites of DTPA and EDTA (Ternes et al. 1996).

(strong) chelating agents, except perhaps for special processes, where product qualities may be somewhat lower in certain aspects but considered acceptable because of the (potential) environmental burden avoided. Unlike the hazardous potential of nuclear power, which is judged as socially unacceptable by large segments of the population, including many experts, such a phasing out of widely applicable chelating agents, however, is unlikely to be seriously considered by relevant social groups at present.

Referring once more to the example of new types of photographic processing machinery implying a lot of water, energy and chemicals savings, it is obvious that EDTA substitution is only of secondary importance for the general goal to reduce or prevent environmental pollution, as long as EDTA is not considered a serious environmental threat. In many cases there exist more effective opportunities for environmental management to reduce environmental pollution by corresponding environmental innovations than by substituting EDTA. Therefore, the innovative efforts taken to reduce EDTA release, for instance substitution by IDS and EDDS, EDTA biodegradation, or safe waste disposal by reusing EDTA containing wastes, finally resulting in EDTA degradation, may well be considered true environmental innovations if they imply favourable ecoaccounts compared to EDTA use or release. However, their costs should remain limited, when one compares their benefits with other, possibly more significant non EDTA-related environmental innovations, which might well be achieved by the same actors.

5.2 The central role of market opportunities and corporate capacities

Comparing the various innovative efforts undertaken to reduce EDTA use or release, their successful diffusion exhibits some features which tend to confirm the familiar hypothesis that - given equal technical viability of innovations addressing similar objectives - corporate capacities and market opportunities to a large degree decide about their success on the market. Although technical maturity and reliability of the various innovations clearly differed and mattered, and although equality in technical viability can never be assessed precisely, the examples tend to support this hypothesis. Besides further significant criteria such as safety for producers, users and third parties, and relative advantages in cost, the range of possible applications (market volume), and the power of promoters and implementers of an (environmental) innovation clearly matter.

In this respect the interesting comparison is biodegradation of EDTA by bacteria developed by a university institute with small resources and no market power and access, dependent on the support of cooperating institutions[43], on the one hand, and the development and marketing of the medium-strong chelating agent MGDA by BASF, on the other hand. Thus, the university research group has no real opportunity to launch, upscale and test its technology even with a highly competitive price on the market, until EDTA users are willing to cooperate and to experiment with this technology. Past experience, however, of the research group was rather disappointing

[43] The other example of biological degradation of EDTA developed by Akzo Nobel offers only a rather limited range of application because of atypical alkaline conditions of p_H>8.5 required.

because EDTA users seemed to be rather sceptical about this technology in view of perceived additional waste water management skills and costs required and of its still unproven technical viability at the operational level of industrial plants. BASF, on the contrary, disposes of the resources and established relationships with customers to finance upscaling experiments testing MGDA, to influence market access by appropriate marketing campaigns, and to weather temporary lacking market acceptance. Thus, gradual though limited market penetration of MGDA meanwhile can be observed although it is more expensive than EDTA and its performance as a biodegradable medium-strong chelating agent is not as good as that of EDTA[44].

Comparing different EDTA substitutes offered by BASF, such as ISDA, MGDA, DTPA, PDTA or NTA, their market success or failure most likely correlates with their technical viability and market acceptance, whereas the supporting corporate capacities, which have not been studied, were probably the same, though not necessarily so.

Comparing corporate capacities and market chances of the two enzyme-based cleaning procedures tested by MILEI, they can be judged as rather equal. It were technical problems that let MILEI decide after one and a half years to change from one enzyme-based cleaning procedure to another.

Thus, the examples confirm that usually anyone of all major criteria listed, namely technical maturity and reliability, safety and environmental compatibility, relative advantages in cost, corporate capacity and market opportunity (largely determined by the range of possible applications), alone is crucial for market success of environmental innovations.

5.3 The impact of political action and regulatory framework conditions

From the research perspective of this case study to investigate the role of EP, ETP and EP/ETP cooperation in stimulating and supporting environmental innovation it has to be asked if and how both political action and regulatory structures mattered for EDTA-related environmental innovations.

Concerning the funding of corresponding R&D projects, technology policy obviously played only a minor role because it expected industries to finance relevant R&D by themselves, at least as long as EDTA use is not concretely regulated or prohibited. The BMBF co-funded a university project on biological EDTA degradation once, but was not interested in funding the subsequent project because of a parallel project proposal addressed to the AIF. Because many EDTA users are medium and small sized companies, they are reluctant to undergo the bureaucratic procedures required for public R&D subsidies. Moreover, public resources were spent within measurement programs and related studies on data gathering concerning EDTA and other not readily biodegradable chelating agents, which did not intend to induce environmental innovations per se.

[44] Compared with EDTA, the presently available knowledge about its potential environmental impacts is poorer, too.

In order to foster EDTA reduction efforts reducing EDTA use and release in industries, UBA strove to disseminate corresponding R&D results by providing leaflets and information brochures, and by approaching responsible industrial associations.

Concerning policy impact, it was mainly the interplay of existing or aspired environmental regulations and environmental policy action, described above, that created political pressure on industries to also invest in R&D projects in favour of reducing or avoiding EDTA release.

Leaving aside local experiments with and applications of new technologies because of expected or experienced EP activities and regulations, which led to adaptive innovations concerning process optimisation (see the examples of MILEI and, partly, BASF), the major innovative efforts refer to EDTA substitutes and their application in formulations and cleaning devices, on the one hand, and to improvements in machinery and processing technology primarily oriented towards overall efficiency gains and thus savings in energy, water and materials needed, on the other hand, which implicitly lead to reduced EDTA release. These innovative efforts, however, are mainly undertaken by large corporations who decide to do so because they view them embedded in their general R&D strategies, namely to search in general for promising substances to be utilised in new formulations, new application technologies, or even new areas of application and to be sold globally. They do so because they expect to develop an - at least in the long run[45] - profitable product needed to remain competitive on the world market. And they do so because corporate strategies of responsible care meanwhile are in many cases rather well established[46] leading to systematic regard of environmental concerns in corporate strategies and decisions (cf. Conrad 1998). Clearly, within these corporate strategic orientations EDTA reduction is only one (minor) element to be aimed at by R&D projects, which generate their own dynamics, however, to be carried on and to lead to marketable products, once they have been started.

Thus, already for economic reasons these innovative efforts did not result from (corporate) reaction to specific EP activities or (pending) regulations in one particular country such as Germany.

Thus, within a certain variation according to innovation type and area of application, EP may have well enhanced market introduction of environmental innovations described above, but hardly induced them. This may be somewhat different in case of strict unequivocal environmental regulations, but even then a corporation with a global reach will balance probable costs and benefits of necessary R&D investments against transferring its production processes concerned or leaving one national market concerning those products affected by these regulations. Typically, industrial lobbying is

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[45] For instance, if EDDS will be used in large quantities and will be offered by more than one producer in the future, there is good reason to believe that its production and application costs should not be much different from those of EDTA, as indicated by Procter & Gamble in the detergent sector which had already replaced EDTA by EDDS in its cleaning systems.

[46] These strategies originated from realising the (indirect) costs likely to be borne at least in the longer run, which are affiliated with emissions polluting the environment and with the negative image of an environmental polluter.

strong enough to avoid in most cases legal ban of hazardous substances and products until profitable alternatives have been developed (cf. Jacob 1999).

6 Interpretation perspectives

This section summarizes the major factors at different levels underlying EDTA-related environmental innovations, with special consideration of policymaking and interpolicy coordination. This is done in conformity with an interpretation perspective according to which the interaction dynamics of structural, institutional, actor, situational, problem perspective and strategic capability factors ultimately determine innovation processes.

Because the innovation processes addressed have not been studied on a micro-level, only plausible appraisals and no compelling evidence about the significance of the factors identified here can be given. Certainly, the theoretically crucial reference to the interaction dynamics of structural, institutional, situational, framing and action-oriented factors of influence which tend to mutually reinforce their impact on the innovation processes appears to be a reasonable conceptual assumption. Without their substantial description, however, the conclusion that these interaction dynamics essentially underlie the innovation processes described remains only a plausible hypothesis not tested by empirical reconstruction and evaluation.

6.1 Structural framework conditions

Structural framework conditions refer to the manifold (contextual) settings that influence the direction and evolution of social processes independent of actors' (current) articulation of interests and modes of procedure. Concerning the EDTA-related environmental innovations described, these structural framework conditions relate in particular to the domains of ecology and health, economics, corporate organisation and culture, law, politics and administration, general sociocultural conditions, and the (national) innovation system. Without going into their in principle endless description, I summarize key contextual settings already described in previous sections.

Environmental and health problems and corresponding sociopolitical concerns mattered as legitimate (rational) criteria to question EDTA release and to structure corresponding controversy, to examine regulation of EDTA use and to negotiate voluntary agreements on reducing EDTA release, and as potential sources of economic costs due to (additional) environmental protection measures required, or due to losses in market share resulting from the negative image of being an environmental polluter.

Economic criteria and judgements largely determined investment in R&D projects developing EDTA substitutes and their market success.

Corporate organisation and culture allowed to pursue longer term R&D projects in large chemical corporations producing chelating agents or supplying them in their (cleaning) products, whereas the corporate organisation and culture of many EDTA users reflected their more short term orientation to quickly react to market fluctuations. Furthermore, the respect for responsible care as a corporate goal of the chemical industry (VCI 1999) helped the industry accept the EDTA issue as a legitimate area for corporate measures to be taken. The preference for voluntary agreements by politico-administrative bodies partly deviated from predominant approaches of bureaucratic procedure and control, but was well in line with the growing practice of public-private covenants in environmental policy, seen as a remedy to unimplementable traditional command-and-control policy when addressing complex regulatory issues (cf. Knebel et al. 1999).

The relevant legal, political and administrative conditions concerned licensing procedures and costs required for new substances such as IDS or EDDS, the doubtful legal justifiability of a ban on EDTA, the German federal system of dividing responsibilities between federal, state and municipal authorities, the significance of environmental regulation on the EU level, and the legally justified confidence of ETP that necessary private R&D investments can be expected.

General sociocultural conditions[47] typically tend to play the role of background variables where some of them, namely general environmental awareness and the eigendynamic of a commitment once it has been made, probably did support the innovation processes. The German landscape of R&D institutions and technology policy arrangements could well support EDTA-related research, but was hardly important for EDTA-related innovations because major R&D projects and their funding occurred in R&D units of large chemical corporations located in various Western countries.

6.2 Actor networks and institutional eigendynamic

The actor constellation can be characterized as many, often loose networks constituted according to a sectoral and a functional dimension which refer to the various industry sectors concerned and to research, business and regulatory tasks, respectively. That this actor constellation is not a mere analytical construct, created by the EDTA focus of this case study, is due to the mutual communication processes installed by the annual EDTA meetings, which generate some common orientation and affiliation of these networks. The BMU and later UBA were the key environmental policy actors that primarily initiated and organised these communication fora focusing on EDTA, first, on the one hand, and reorienting them to more general issues such as not readily biodegradable chelating agents, on the other hand.

[47] One may list here the modernization capacity of a society, the importance of the state and public policy, the importance of public debate and the equivalent strength of civil society, the extent of division into different social classes or strata, the degree of public participation and socio-structurally entrenched substantive democracy, the significance of self-responsibility and liability of social actors, the degree of legalism, decentralized versus centralized (political) culture and decision-making procedures, the importance of postmaterialistic value orientations, environmental awareness of and behaviour by main actors and the population in general, and the significance and social influence of environmental NGOs.

Concerning EDTA-related R&D projects, the corresponding knowledge networks usually pursued their tasks in a cooperative manner and professional atmosphere, though the project results were quickly translated within the related business networks into (economically justified) decisions to go on or to finish a test experiment and into marketing strategies likely to oversell the product developed.[48] Furthermore, the willingness of most actors, involved in EDTA discourse and politics, to communicate, collaborate, and commit themselves to voluntary declarations or agreements in spite of opposing opinions and interests was stimulated by the structural framework conditions just listed, and also contributed to some degree to engagement in innovative efforts of substituting EDTA use or reducing its release.

Once personal commitments had been made, usually an institutional eigendynamic[49] developed to some degree in all network types, be it knowledge, business or regulatory networks. As indicated by concrete examples described above, these networks stabilised the activities started and tended to mutually reinforce each other, because normally development of an EDTA substitute, investments in its production, marketing and sale, and regulatory action in favour of EDTA substitution mutually presuppose each other. Therefore the juxtaposition of these institutional eigendynamics quite likely was favourable for EDTA-related innovation processes.

To emphasize the role of an institutional eigendynamic does not invalidate, however, the essential role of individuals and situational factors. Whereas the significance of the BMU ministerial director's commitment and political competence for initiating EDTA meetings and achieving the EDTA declaration has to be underlined, although it had no direct impact on related R&D projects, the interest of BASF as a member of the chemical industry in overcoming its negative (public) image as an environmental polluter in the late 1980s and its established waste minimization program were favourable situational factors supporting the considerable efforts of BASF to drastically reduce its EDTA release. Similarly, the low and varying price of Bayer's basic chemical MSA, inevitably occurring in chemical production processes of some production units, was a major situational factor inducing the development of IDS.

6.3 Varying problem perspectives and strategies for solutions

As pointed out in section 5.1 the cognitive framing and corresponding evaluation of EDTA use and release of actors varied considerably in significant conformity with their (organisational) interests. These differences mattered when judging the necessity and urgency to take efforts towards reducing EDTA release, as well as preferable points of departure for these efforts (e.g. waste water treatment versus purification of drinking water). They mattered much less, however, when discussing the basic reduction options of EDTA release (renunciation, reduction, substitution, degradation), and when

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[48] Corresponding examples are ADA propagated by Agfa, or alkaline biodegradation advertised by Akzo Nobel.

[49] This institutional eigendynamic typically stems from (central) underlying (formal) organisational interests.

developing specific products and technologies in this respect. This feature is due to the fact that the actors actually involved in a certain EDTA topic were well aware of these different options, and recognised and admitted that the advantage of one of them is debatable. For it depends on features such as its technical and social viability, its relative costs, its environmental impacts compared to those of the other options, and the size of EDTA release to be avoided, which all vary according to the area and type of EDTA application.[50] Furthermore, for the success of an innovation, criteria of technical and economic viability tend to count more than general personal preferences and valuations of those, who are (as scientists) professionally engaged in actual R&D projects.[51]

Thus, one may conclude that problem perspectives and strategies for solutions, shaped by the economic, political and technological selection environment, influenced the selection of R&D projects considered worthwhile. The R&D processes themselves, however, followed a rather predictable technological trajectory (cf. Dosi 1982, Nelson/ Winter 1982) and were in their substantive results less influenced by these general cognitive framings. Again, the (EDTA-related) problem perspectives and strategies for solutions of those promoters and implementers, who have sufficient power and capacity, have well influenced acceptance and diffusion of these environmental innovations as a whole, comprising their economic and social viability as well.

6.4 The role of policy making and interpolicy coordination

As described in previous sections, EP institutions played a key role in setting EDTA on the political agenda and in organising information gathering and exchange, voluntary declarations and agreements, and effective action. The in functional terms relevant ETP institutions were UBA and the PTWT which are subordinate to the central environmental policy and technology policy bodies, i.e. BMU and BMBF respectively. They did some funding of R&D projects and kept track of ongoing R&D activities at a survey level, as recorded in the documents of the annual EDTA meetings.

As major innovative activities addressing reduction and substitution of EDTA use or release were primarily undertaken in large chemical corporations rather uninfluenced by

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[50] A striking example is the technical viability of three out of the four basic options concerning EDTA use in photo baths: EDTA release can be reduced by rather closed cycle photo processing systems thereby minimizing waste accumulation and EDTA diversion in particular; EDTA use can be substituted or reduced by (adding) EDDS, which is expensive, or by PDTA, which is also a not readily biodegradable chelating agent; EDTA can be biodegraded by bacteria, what is assumed to be relatively cheap; or EDTA use can be continued in new machinery where the waste can be processed and then reused in the cement industry, which may well turn out to be the cheapest future option.

[51] This assertion does not deny that scientifically based empirical statements are in the last resort always shaped by normative conceptualizations, but it denies their arbitrariness against constructivist theories. Certainly, criteria of technical or economic viability leave considerable room for interpretation (cf. Ravetz 1971, Freeman 1974), but do not permit arbitrary judgements. For instance, it may well be possible to argue the superiority of the enzyme-based cleaning procedure of Henkel Ecolab over that of DiverseyLever, but one can hardly argue that each of these cleaning systems does not avoid use of EDTA.

ETP, it played only a minor role concerning EDTA-related environmental innovations, whereas EP probably at least pressed industries to tackle them.

Furthermore, policy making played some role in the innovation processes by deciding upon environmental and technical standards and by licensing new substances and technologies in the regulatory networks. In view of these circumstances there was no need for effective EP/ETP interpolicy cooperation beyond ordinary coordination routines (see Conrad 2000a), particularly because UBA as the key actor took responsibility to care for both EP and ETP matters from 1992 on.

Nevertheless, weaknesses of interpolicy coordination can be identified in at least two respects. Because of differing interests and orientations in different policy areas, such as water and chemistry policy, as well as in federal, state and municipal EP institutions the corresponding need for bargaining and coordinating processes within the field of environmental policy sometimes led to unsatisfactory results if claiming a clear and consistent EP. Whereas these deficiencies cannot be completely avoided within the given institutional setting of EP and showed no extraordinary extent, coordinating efforts between environmental and health policy, i.e. between BMU and BMG, and more substantively between UBA and BgVV, to balance their differing concerns of environmental protection and health care, took rather long time until the diverging policy recommendations to substitute slowly biodegradable EDTA by rapidly biodegradable NTA, and to avoid NTA use because of potential carcinogenic risks were explicitly reconciled around 1995 by recommending NTA as an EDTA substitute only up to certain amounts. This agreement could have been achieved more rapidly, especially in view of the understandable unwillingness of industries to substitute technically highly useful, but not readily biodegradable EDTA by another chelating agent NTA which is questioned for analogous safety reasons by health policy or even legally restricted to special applications in other countries.

7 Typical features and summarizing conclusions

This final section tries to summarize the main characteristics of the case study and to draw corresponding conclusions, first concerning EDTA discourse and politics, and then concerning EDTA-related environmental innovations.

1. The rise of EDTA as an environmental issue was due to incidental recognition of high EDTA concentrations in surface waters in NTA-related measurement programs, political pressure of water utilities to prohibit significant EDTA release in waste water, the engagement of EP to find a viable regulatory solution to this environmental problem, and the willingness of the chemical industry, particularly BASF, to reduce EDTA release in order not to undermine viable dialogue established with water supply utilities.
2. Despite a lack of similar endeavours in other countries EP succeeded in stimulating efforts to significantly reduce EDTA release, in particular by aspiring to a voluntary declaration and subsequent voluntary agreements. Supported by continuous debate

in EDTA meetings and by the eigendynamic of commitments made by participating actors, these efforts led to substantial results, though not as much as had been envisaged. It appears less likely that these results would have been equally achieved by attempts to pass general formal environmental regulations on EDTA production, use or emission.

3. This environmental policy success was certainly facilitated by contextual conditions such as the strong interest of companies to avoid direct environmental criticism and blame, or situational economic incentives for chemical corporations to search for EDTA substitutes (e.g. IDS). Thus, environmental concerns primarily mattered because they were coupled to private and public R&D interests as well as corporate economic and genuine political (organisational) interests of important actors based on the overall social legitimacy and significance of environmental protection and ecological sustainability.

4. The cognitive framings of the actors participating in EDTA discourse and politics clearly varied in accordance with their interests and problem perspectives. The social learning processes resulting from EDTA-related debate and action contributed to the change and differentiation of these cognitive framings. In particular most actors recognised the need to distinguish between different areas of EDTA use, to involve and to coordinate EDTA producers, suppliers and users, to balance the impacts and viability of different (technical-fix) strategies capable to reduce EDTA release (renunciation, reduction, substitution, and degradation), and to replace the ecologically inappropriate focus on a single substance EDTA by embedding it in a broader perspective. Such a perspective comparatively assesses the various environmental and health impacts of chelating agents in general (e.g. the study carried out by the ESWE institute mentioned above in footnote 16) and relativizes the environmental importance to avoid EDTA release in view of other well feasible and more beneficial environmental improvements.

5. In such a more holistic ecological perspective environmental trade-offs in several dimensions became obvious, such as substitution versus well-functioning waste management of EDTA, or considerable savings in water and energy consumption versus avoidance of a specific substance, implying some potential negative environmental impacts but no serious health risks[52], in photo processing systems.

6. Similar to the fundamental difficulties and limitations of EP to influence and control environmental behaviour of the population at large, consisting of millions of individual consumers, EP ultimately had to rely on the willingness and commitment of many companies in diverse industries using EDTA in comparatively small amounts in order to reduce EDTA release, stimulated by persuasive action of relevant industrial associations which had been approached by EP for this purpose. Because there were only few people in the BMU and in UBA in charge of dealing with EDTA subjects in detail, EP was not only confronted with inevitably high

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[52] This trade-off between quantity and quality underlies a criticism voiced against the MIPS concept, advanced by Schmidt-Bleek 1994.

transaction costs when addressing and controlling specific sources of EDTA release but also with a task overload due to scarce personnel that had to keep track of and administer its activities.[53]

7. In spite of partly prevailing mutually unfavourable stereotyped perceptions of economic and political actors, respectively, cooperative attitude and concerted action stimulated by the BMU and later on by UBA resulted in effectively tackling an environmental issue by voluntary declaration and agreement without remarkable public controversy, without involvement of environmental action groups, and without legal conflicts between public bodies and private industrial corporations.[54] Otherwise, undoubtedly more manpower and time would have been mustered for EDTA discourse and politics.

Concerning EDTA-related environmental innovations, only some general observations can be presented, because individual innovation processes have not been investigated at the micro-level.

1. The economic, political and technological selection environment determined to a considerable degree the various technological trajectories followed by the innovation processes.
2. The environmental innovations arising typically were technical process innovations or a combination of product and process innovation rearranging and optimising chemical processes in various industries using EDTA.
3. Concerning producers and suppliers of chelating agents, their EDTA-related innovative efforts were embedded in general research programs elucidating the pronounced strategic capabilities of corporations such as BASF, Bayer, Henkel or Unilever in managing innovations.
4. Significantly, being strongly opposed to further duties to extract chemicals released into water bodies, water utilities pursued only small-scale R&D activities to eliminate EDTA in water treatment plants, for example by ozoning or oxidation processes.
5. Without significant public funding policy making and interpolicy coordination of EP and ETP in most cases had at best an indirect impact on these innovation processes reinforcing them to some degree by promoting regulatory framework conditions and monitoring programs.
6. Consequently, various relatively separated knowledge, business and regulatory networks originated from these EDTA-related innovative efforts.
7. Comparing different R&D projects leading to technically viable environmental innovations of reducing, substituting, or degrading EDTA (use), the central importance of corporate capacities and market opportunities for their successful

[53] Already the transfer of the task to organise the annual EDTA meetings from the BMU to UBA was partly due to cut-backs in personnel within the corresponding BMU unit.

[54] Certainly, this is more likely to happen as long as no key product or key production process is concerned by environmental policy regulation.

diffusion becomes obvious. Thus, serious obstacles to the innovation processes referred more to their social than to their technical and time dimension.

8. The focus on EDTA as a single substance, partly enforced by EP, is in general inappropriate for achieving innovative environmental improvements in their most beneficial form. These potentials can be better recognised in a more holistic perspective aiming at ecological sustainability, assessing environmental impacts of the whole cradle-to-grave value chain encompassing the total product life-cycle, and taking into account trade-offs between different environmental objectives. Therefore, environmental innovations addressing chemical processing arrangements as a whole typically include many more environmental improvements than EDTA substitution. They require, for instance, cooperation between the machine building and chemical industries to develop closed cycle photographic processing systems, where the recovered waste material can still be reused in the cement industry. In the EDTA discourse this option was consciously taken into account, however, neither by the photochemical industry nor by environmental policy.

Altogether, environmental policy successfully organised multiple efforts to reduce EDTA release on the basis of voluntary agreements in Germany. These voluntary agreements enhanced, but did hardly induce corresponding environmental innovations, mainly in industry, and also contributed to learning processes among the actors, participating in EDTA discourse and politics, in the direction of a more holistic (policy) perspective towards ecological sustainability.

8 Literature

AIS, Environmental Safety Working Group, 1987: An assessment of the implications of the use of EDTA in detergent products

BASF, 1987: EDTA. Manuscript, Ludwigshafen

Bayer, 1999a: IDS Na-Salz. Eine neue umweltfreundliche Alternative zu klassischen Komplexiermitteln. Leaflet, Leverkusen

Bayer, 1999b: PASP Na-Salz. Ein neues, biologisch abbaubares Dispergiermittel. Leaflet, Leverkusen

BUA, 1996: Ethylendiamintetraessigsäure/Tetranatriumethylendiamin-tetraacetat. BUA-Stoffbericht 168. Stuttgart: Hirzel

Conrad, J. (ed.), 1998: Environmental Management in European Companies. Success Stories and Evaluation. Amsterdam: OPA

Conrad, J, 2000a: Interpolicy Coordination in Germany: Environmental Policy and Technology Policy, Zeitschrift für Umweltpolitik und Umweltrecht 23: 583-614

Conrad, J, 2000b: Eco-efficient fertilizers: an environmental innovation organised by a corporation and promoted by technology policy. FFU-report 00-03, Berlin

Conrad, J, 2000c: Ecologically sound pulp production: how the interaction of world market conditions, corporate capabililty and environmental policy determines success and failure of environmental innovations. FFU-report 00-05, Berlin

Dijken, K. van et al, 1999: Adoption of Environmental Innovations. Dordrecht: Kluwer

Dosi, G, 1982: Technological paradigms and technological trajectories. A suggested interpretation of the determinants and directions of technical change, Research Policy 11: 147-162

Freeman, C, 1974: The Economics of Industrial Innovation. Harmondsworth: Penguin

Huber, J, 1995: Nachhaltige Entwicklung. Berlin: edition sigma

IIUW (Interdisziplinäres Institut für Umwelt und Wirtschaft) et al, 1998: Towards an integration of environmental and ecology-oriented technology policy. Stimulus and response in environment related innovation networks (ENVINNO). Project proposal, Vienna

Jacob, K, 1999: Innovationsorientierte Chemikalienpolitik. München: Herbert Utz Verlag

Kernforschungszentrum Karlsruhe. Projektträger Wassertechnologie und Schlammbehandlung (ed.), 1991: Aquatische Umweltverträglichkeit von Nitrolotriessigsäure (NTA). Karlsruhe

Knebel, J. et al, 1999: Selbstverpflichtungen und normersetzende Umweltverträge als Instrumente des Umweltschutzes. Berlin: E.Schmidt

Nelson, R, Winter, S, 1982: An Evolutionary Theory of Economic Change. Harvard University Press

Nörtemann, B, 1999: Biodegradation of EDTA, Applied Microbiology and Biotechnology 51: 751-759

Ravetz, J, R, 1971: Scientific Knowledge and its Social Problems. Oxford University Press

Schmidt-Bleek, F, 1994: Wieviel Umwelt braucht der Mensch? MIPS - Das Maß für ökologisches Wirtschaften. Basel: Birkhäuser

Ternes, T.A. et al, 1996: Identifizierung und Nachweis neuer Metabolite des DTPA in Fließgewässern und Trinkwasser, Vom Wasser 87: 275-290

UBA, 2000: Risk Assessment. H_4EDTA/Na_4EDTA. UBA-Draft, Berlin

VCI, 1999: Responsible Care. Report 1999. Frankfurt