THE JOURNAL OF PREVENTIVE MEDICINE
2001; 9(4): 41-51

CONTAMINANTS OLD AND NEW – INNOVATION IN PREVENTION

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Invited Paper, Occupational Hygiene Symposium (Iasi, Romania, 16-17 May 2001) on "Prevention in Exposure to Occupational and Environmental Contaminants"

Abstract. Environmental issues are becoming increasingly complex, however, multidisciplinary co-operation may yield unprecedented opportunities for innovative solutions. Two extreme and opposing cases are used to illustrate the potential and pitfalls of this approach for *prevention*. Metal mining is one old industry which presents a clear and present danger to man and the environment. During the 1998 calamity in Spain 5 million cubic metres of acidic mining waste washed into the vulnerable Donana Wetlands, a well-known bird sanctuary. In order to prevent similar catastrophes in the future, a preliminary EU risk inventory was made by combining environmental toxicology and remote sensing. Meat production is another old industry. It is increasingly recognized that a steadily growing world population plus a rapidly increasing per capita meat consumption will pose unprecedented environmental problems in the near future. Therefore, the PROFETAS (Protein Foods, Environment, Technology And Society) research programme studies the potential of a (partial) transition from predominantly animal to plant protein consumption. Major social, environmental, and occupational consequences of a partial transition from meat to novel (plant) protein foods (NPFs) are discussed in the light of recent food scares (BSE, GM, etc.).
Key words: prevention, environment, society, technology, contaminants, innovation, multidisciplinarity,metal mining, meat industry, industrial transformation.

Rezumat. Problemele de mediu devin din ce în ce mai complexe şi cu toate acestea, cooperarea multidisciplinară poate crea ocazii fără precedent pentru găsirea de soluţii novatoare. Exemplificarea potenţialului dar şi al capcanelor impuse de acest mod de abordare în scop de *prevenţie* se face în două cazuri opuse. Mineritul metalifer este o industrie veche ce reprezintă un pericol evident pentru om şi pentru mediul înconjurător. În 1988, în Spania au fost deversate 5 milioane de metri cubi de reziduuri acide în binecunoscuta rezervaţie naturală pentru păsări, mlaştinile Donana. Pentru a preveni catastrofe similare, la nivelul UE s-a întocmit un inventar preliminar utilizând o combinaţie de toxicologie de mediu şi supraveghere de la distanţă. Producţia de carne este o altă industrie veche. Din ce în ce mai mult se recunoaşte faptul că o creştere constantă a populaţiei şi a consumului de carne pe cap de locuitor, vor crea în viitorul apropiat probleme de mediu fără precedent. Din acest motiv, programul de cercetare PROFETAS (Hrană proteică, Mediu, Tehnologie şi Societate) studiază posibilitatea unei tranziţii parţiale de la consumul predominant de proteină animală la cel de proteină vegetală. În cadrul programului se studiază efectele sociale, de mediu şi ocupaţionale ale tranziţiei de la carne la noi proteine vegetale (NPFs), având în vedere şi problemele legate de alimente (encefalopatia spongiformă bovină -BSE, recolte modificate genetic - GM, etc.)

Cuvinte cheie: prevenție, mediu înconjurător, tehnologie, contaminanți, inovație, multidisciplinaritate, minerit metalifer, industria cărnii, transformare industrială.

INTRODUCTION

This paper has been devoted to prevention, contrasting old with new. With regard to old methodologies, in the past the world used to be simple. Unlike today, mastering one discipline such as chemistry or toxicology to the full was possible still and usually sufficed to solve the prevention problems at hand. Nowadays, all human activities and their effects are intertwined, resulting in a more complex world. Everyone, even the general public, increasingly requires at least some working knowledge of many subjects at once, such as geography, biology, physics, as well as economics, law and other social sciences. Most of all, however, everyone needs to know about communication. As will be clear from the following example, communication is much more than language.

In March 1995, there was a terrorist attack with the nerve gas Sarin in the Tokyo subway system. Later analysis (1) showed two unexpected results. The first is that even an environmental toxicologist may be surprised to learn that, in comparison to the commuters in the subway system, a relatively large proportion of the hospital staff fell victim to the gas. In fact, over 20% of the medical staff complained of symptoms and signs of secondary exposure. The underlying cause was that Sarin remained a fluid in the cold subway and ambulances, but the droplets started to evaporate in the warm hospital buildings. The second surprising conclusion was that some victims fell due to communication problems between hierarchical organisations such as police and fire brigade on the one hand, versus more democratic networking organisations such as ambulance crews, on the other hand.

When a fire or police officer issued an order, he expected to be obeyed, so he turned around on his heels and left. Medical people may have other priorities and act accordingly, so a mismatch can occur in mutual expectations and communications. In short, communication has cultural aspects.

In summary, the world has become more complex than it used to be. For truly innovative solutions, environmental and occupational health issues often require input from many scientific disciplines. However, such input is often available and may lead to interesting opportunities for prevention through co-operation between seemingly unrelated scientific disciplines. In this paper two entirely different cases will be presented, metal mining and protein production, followed by a general conclusion sketching future perspectives.

CASE 1. METAL MINING

Metal mining has taken place for thousands of years. Its effects on occupational and environmental health

have been known for centuries. Recently, however, the growing scale of mining operations has resulted in incidents of at least the same order of magnitude as calamities in the pharmaceutical industry, such as the 1986 fire at Sandoz in Basel, Switzerland. During the latter incident, 30 tons of chemical wastes entered the river Rhine, killing fish for 500 km downstream, predominantly as a result of 200 kg of mercury compounds.

In 1998, a calamity of a comparable type occurred in the Los Frailes mines in southern Spain. A tailings lagoon dam broke and 5 million cubic metres of acidic mining waste loaded with heavy metals washed into the vulnerable Donana Wetlands, a well-known bird sanctuary. This gave rise to wide-spread concern. In order to prevent similar catastrophes in the future, a preliminary EU risk inventory was initiated (2), since the chances for repetition of a similar catastrophe somewhere in Europe were essentially unknown.

The approach of this desk study was to start with an inventory of metal mining sites in all 15 countries of the European union (EU-15), on the one hand, and nature conservation sites, on the other hand. In parallel, a literature study should reveal reported incidents, impacts on environment and health, and EU legislation both on mining and on nature conservation. The ultimate goal was to confront a list of potentially hazardous mining sites with a list of potentially vulnerable nature conservation sites in order to geographically pinpoint high-risk locations.

From the beginning of the project it was clear that the literature search on health and environmental impacts would be relatively simple, but that the bottle-neck would be data collection on mining sites in general, and those with potentially hazardous lagoons, in particular. This aspect of industrial operations is not usually advertised in the publicly available literature.

The initial results of the study were even far below these expectations. It turned out that data on active and abandoned mines - let alone tailings lagoons - were not centrally available anywhere in the European Union. In fact, these data were often hard or impossible to come by even at the level of the national governments. The same held for major incidents and risks concerning mining. More surprising was the fact that - although a large number of international and European conventions on nature conservation exist - there is no unifying legislation on industrial activities disallowed near conservation sites. The same held for legislation on mining and waste disposal regulations. Depending on the country, some directions may be available at the national, state, county and/or local level, generally without too much harmonisation. In summary, data collection was tedious and incomplete.

However, it had been anticipated that identifying the location of mining waste lagoons by contacting European and/or national governments plus the

mining industry would not be straightforward. Therefore, the project design included a small pilot study to check the feasibility of locating mining waste lagoons by means of remote sensing. Consequently, pre-disaster satellite images of the Donana region were analysed by computer. As it turned out, the Los Frailes lagoon displayed a high reflectance at green and red wavelengths, clearly distinct from nearby natural waters. In fact, the yellowish green-orange colours displayed by acid mine drainage is easily identified as being due to flocculating ferric hydroxides, which are released during any mining operation. The feasibility of the method was confirmed by identifying (in the same satellite image) a water with the same spectral properties as a tailings lagoon belonging to the nearby Rio Tinto mine (2).

In addition to identification, remote sensing methods have the advantage that 3-D spatial relationships between hazardous lagoons and vulnerable areas can be established. The main advantage, however, is that hazardous lagoons can be detected without active co-operation from companies or authorities being required.

In conclusion, remote sensing had proven to be a labour-intensive but useful method to locate tailings lagoons, complementing literature and desk research. The report advising a full risk analysis at the European level was presented in Brussels early 1999. One year later, early 2000, a dam breaking in the north of Romania caused 100,000 cubic metres of mining waste laced with cyanides and heavy metals to run into a tributary of the river Tisza, killing fish downstream as far as the river Danube, crossing Hungary and entering Romania again in the southwest. Unfortunately, the multidisciplinary study mentioned above had not resulted in prevention of this incident in Baia Mare.

CASE 2. PROTEIN PRODUCTION

A more systematic way to deal with prevention in the long term is the research focus of 'Industrial Transformation' (3).The underlying rationale is that the simultaneous increase in the world population and per capita income (4) is so rapid - with concomitant deteriorative effects on the environment - that in order to achieve and maintain sustainability a stepwise transformation is required, rather than a gradual change, in particular in the areas of food, water and energy production (5).

Food, our lives depend on it. Not just directly by providing nutrients, but also indirectly by generating income (6). Probably due to its essential role, food and food quality are presently in the floodlights of societal attention (7,8). In addition to its nutritional and economic values, food is endowed with important symbolic qualities as well (9).

The food issue may be approached from many perspectives, but there is no denying that a major proportion of global environmental pressure is generated by food-related human activities (10,11,12,13). Crops are

produced, transported, processed and turned into food products in ever larger volumes, with ever increasing impacts on the environment. Continued growth of the world population and consumer affluence are both important driving forces (table 1).

Table 1. FAO projections of world population and meat production

year	world population (billion)	meat production (million tons)	per capita meat consumption (kg/yr)
1950	2.5	44	18
1970	3.7	100	27
2000	6.0	232	39
2030	8.1	359	44

Source: FAO (12)

Within the realm of food, meat takes a unique place. Its production is considered responsible for a disproportionate share of environmental pressure, mainly due to the inherently inefficient conversion from plant protein to animal protein. Already we are feeding 40% of the world grain harvest to livestock (14). When striving for sustainable food production and consumption systems (15), therefore, the protein chain is a good place to start for more than one reason (16).

Self-evidently, there is a lot of discussion on exactly how much plant protein (say, from soy) and how much carbohydrate (say, from grain) is required to produce one kg of meat, because this depends on local circumstances (4,11,17). It may be more significant, however, that grain as well as protein-rich feed crops such as soy and peas can be utilised for direct human consumption, rather than indirectly via meat production. Already, food and feed crops are competing for land and water and this will doubtlessly increase in the near future (13,11,12). A substantial amount of environmental pressure (deforestation, loss of biodiversity, soil and water pollution by pesticides, fertiliser and manure, acidifying and greenhouse gas emissions, etc.) can be avoided if society would be inclined to (at least partially) refrain from meat and eating plant protein instead. In terms of 'Industrial Transformation' the issue is to what extent the globally increasing protein demand can be 'uncoupled' from parallel increasing environmental pressure by means of a (partial) transition from animal to plant proteins. In fact, four barriers challenging the feasibility of such a transition can be identified:

1. Social forces are strong. Meat has a high social status (9).
2. Economic forces are strong. Established industrial interests are conservative (6).
3. Technological expertise is lacking. In the 70s, large-scale introduction of textured vegetable protein (TVP) by Unilever failed, allegedly due to insufficient quality of taste and

'mouthfeel' of the product. More recent products such as Quorn by Astra-Zeneca seem to better satisfy consumer demands, but 'still insufficient to expect large-scale adoption', as has been stated in a chapter on 'Constructive Technology Assessment: the case of novel protein foods' (16).

4. Environmental advantages, though theoretically evident, should be more precisely quantified. The meat chain has been optimised for millennia, finding use for every single part of slaughtered animals (skins for leather, hairs for brushes, bones for gelatine, etc.). By analogy, when designing an alternative protein chain, care should be taken to consider the whole chain from production to consumption, not just the protein part. Otherwise, the theoretical environmental gain might be offset by massive waste originating in the non-protein part of the crop.

In order to study the feasibility of the animal to plant protein transition described above, the transdisciplinary PROFETAS (Protein Foods, Environment, Technology And Society) research programme was developed, exploring pathways towards more sustainable food systems (18). The central research theme in PROFETAS is whether a partial transition from animal to plant protein foods in the western-style diet is:

A. more sustainable than present trends
B. technologically feasible
C. socially desirable

The geographic focus is on Western Europe in a global context. Though studying the replacement of animal products by plant protein products, it should be made explicit that the two types of products under study will not be identical, or even similar. Replacing steaks or meat chops is not even remotely considered. The focus is on 'ingredients', more or less unrecognisable bits of scrap meat, which are used as constituent parts of more complex meals, such as - but certainly not limited to - soups or pizzas. Such ingredients are presently often derived from pork scraps, but may be derived from plant proteins in the future, technological innovation permitting. Peas are a promising crop in this regard, containing about 20% proteins. In short, therefore, the focus of the research programme is on 'pigs *versus* peas'.

PROFETAS is a modern research programme (19) combining the Industrial Transformation (15) and Sustainable Technology Development (16) approaches. It displays all four IT characteristics (5) by its focus on a) systems changes, b) the relationship between societal, technological and environmental change, c) the relationship between producer and consumer perspectives, including the incentives and institutions that help in shaping these perspectives, and d) the international scope. With STD it has in common its aim for capacity building, generating a generic toolbox capable of handling future problems, rather than hardwired solutions for presently perceived problems (16).

Innovative visions of the future are developed, and by means of 'backcasting' (in stead of forecasting) alternative options are generated and evaluated. In turn, this requires development of new instruments and methodologies (the toolbox), which are iteratively refined.

Thus, in PROFETAS elements from IT and STD were combined into a novel approach:

- transformation is studied rather than gradual optimization;
- the perspective is chain-oriented with a predominant role for consumer preferences;
- the entire protein chain is considered, from primary production via processing and consumption to waste;
- the overall goal is multidisciplinary (political, social, technological and scientific) design and evaluation of alternative protein production options and their impacts, yielding policy options for policymakers from government and industry.

By January 2000, PROFETAS included 8 PhD students performing basic research on economic, ecological, political, consumer, sensory, chemical, agricultural and technological issues in 5 projects devoted to technological (T) analysis, and 4 projects in social and environmental systems (S) analysis (table 2).

Table 2. PROFETAS study design: issues studied and two-step integration

S1 environment S2 economy S3 society/policy S4 ecology	Analytical PhD student projects	T1 consumer/product T2 flavour/protein T3 texture/protein T4 protein composition T5 supply chain design
Postdoc projects	I1 options for raw materials I2 societal opportunities/barriers I3 economic market feasibility I4 institutional key actors I5 consumer/marketing issues	Sustainable strategy design and evaluation
Programme co-ordination	O1 environment (government) O2 technology (industry)	Development of options for policy

By January 2001, an additional 7 transdisciplinary postdoc projects had started to address market and consumer behaviour, sociocultural lifestyle, legal, institutional, production and sustainability issues, while designing and evaluating strategies to improve sustainability in (protein) food systems in 5 interactive and integrative (I) strategy design

projects. A second, strategic level of transdisciplinary aggregation is performed by two programme co-ordinators, which should finally yield options (O) for sustainable policy to governmental and industrial policymakers (table 2).

A. The *environmental sustainability* studies are addressing issues such as the inherent conversion inefficiency of plant to animal protein. In addition, methodologies are developed to quantify environmental impacts (such as additional deforestation, loss of biodiversity, and increased harmful inputs such as pesticides, manure and fertiliser), and to develop ecological indicators.

B. The *technological feasibility* studies are developing options for alternative plant products (NPFs, or novel protein foods), complying with consumer preferences.

C. The *social desirability* addresses increasing competition between feed and food crops, economic aspects (such as impacts on farmers, retailers and the food industry). In the end, the consumers' rating of taste, price and status of products, and the importance they associate with environmental sustainability will be decisive. Therefore, stakeholders from farmers through consumers will be involved by their participation in feedback meetings.

PROFETAS will continue until 2005. Detailed up-to-date information can be found on the internet:

(http://www.profetas.nl).

In summary, PROFETAS is devoted to preventing environmental deterioration through industrial/societal transformation. Although this transition in the food area is complex, a multidisciplinary research design combined with sufficient attention for transdisciplinary communication may yield innovative opportunities for prevention. Although the potential environmental benefits of a pigs to peas transition seem evident: land-use changes, less eutrophication, pesticides, less antibiotics (90% is added to feed preventively), human health benefits are not directly addressed in PROFETAS. Nevertheless, if such a transition were to materialise, far-reaching consequences for exposure are to be expected, both among workers and the general public (consumers). In this respect, recent food scares such as foot-and-mouth disease and swine fever are affecting livestock, but not human health (table 3).

BSE, however, certainly has some negative impacts on human health, and so do chlorinated or brominated contaminants (such as dioxins, PCBs, flame retardants).

Table 3. Occupational and environmental health consequences of a low-meat diet

risk factor	impacts
foot-and-mouth disease	0
swine fever	0
bovine spongiform encephalopathy	+

halogenated contaminants	+
antibiotics	+
pesticides	+/-
allergies	-
genetically modified crops	-

Furthermore, a low-meat diet will reduce antibiotics input into the environment, because additions to feed will be reduced. Consequently, microbial resistance will be delayed, with positive indirect effects on human health. In general, a low-meat diet will result in less pesticides being applied, however, pesticides for food and feed crops will usually be different. Moreover, the effects on occupational and environmental health can either be beneficial or detrimental, depending on the population involved. Finally, plant products are usually more allergenic than animal products, with concomitant negative impacts on human health. In this regard, GM crops may give rise to additional risks. There is no doubt that their rapid large-scale introduction would be violating the precautionary principle.

CONCLUSIONS

In conclusion, two examples were shown of innovative approaches aiming to prevent occupational and environmental exposures. Metals mining is an old industry, but through multidisciplinary co-operation new solutions for prevention were indicated. Protein (meat) production is also old, but new and innovative solutions are required. PROFETAS is a young research programme, but state-of-the-art (16,5). Its design was an experiment in multidisciplinary research in itself.

From those two extremes two clear lessons emerge. First, in a more complex world, the problems are more complex, but there are also more opportunities for innovative prevention through multidisciplinary scientific co-operation. Second, such co-operation requires extensive communication. Communication requires trying to read one another's thoughts and trying to impersonate other persons. This is not at all simple, because we're used to being among fellow scientists who have similar understandings and frameworks of definitions. However, a 'system' is not the same thing in every scientific discipline. For a biologist, the 'food chain' is the falcon eating the frog eating the flies eating the decaying fruit. For a food technologist, in contrast, it is the farmer's crop being transported to the food factory followed by the resulting product being transported via the wholesaler and the retailer all the way to the consumer. So here language is the all-important medium. Consequently, all statements and definitions should be questioned and be made explicit without any exception.

The bottom line is that innovation and prevention will inevitably flourish under combined conditions of multi-

disciplinary co-operation and explicit communication. Co-operation requiring input not only from different scientific backgrounds, but also from different cultural backgrounds and from different countries.

Acknowledgements
The author gratefully acknowledges The Netherlands Organization for Scientific Research (NWO) for generous financial support (grant number 455.10.300) of the PROFETAS research programme, and the World Wide Fund for Nature (WWF) for support of the mining risk study.

REFERENCES

1. Okumura T., Suzuki K., Ishimatsu S. et al. - *Lessons learned from the Tokyo subway Sarin attack*. Prehospital and Disaster Medicine, 2000, 15, 3, s30.
2. Sol V.M., Peters S.W.M., Aiking H. - *Toxic waste storage sites in EU countries - A preliminary risk inventory (download http://www.wwffreshwater.org)*. ISBN 90-5383-656-X, Institute for Environmental Studies, Vrije Universiteit, Amsterdam, The Netherlands, 1999, 82 pp.
3. Vellinga P., Gupta J., Berkhout F. - *Towards industrial information*. In: Managing a material world: Perspectives in Industrial Ecology (Vellinga P., Berkhout F., Gupta J., eds.), ISBN 0-7923-5206-8, Kluwer Academic Publishers, Dordrecht, 1998, 321-343.
4. Delgado C., Rosegrant M., Steinfeld H., Ehui S., Courbois C. - *Livestock to 2020: The next food revolution (download http://www.ifpri.cgiar.org/index1.asp)*. ISBN 0-89629-632-6, IFPRI/FAO/ ILRI, Washington, DC, 1999, 74 pp.
5. Vellinga P., Herb N. - *Industrial Transformation Science Plan*. IHDP, Bonn (Germany), 1999, 94 pp.
6. Tansey G., Worsley T. - *The food system: A guide*. ISBN 1-85382-277-4, Earthscan, London, UK, 1995, 259 pp.
7. Kloppenburg J., Lezberg S., De Master K. et al. - *Tasting food, tasting sustainability: Defining the attributes of an alternative food system with competent, ordinary people*. Human Organization, 2000, 59, 2, 177-186.
8. Murdoch J., Marsden T., Banks J. - *Quality, nature, and embeddedness: Some theoretical considerations in the context of the food sector*. Economic Geography, 2000, 76, 107-125.
9. Beardsworth A., Keil T. - *Sociology on the menu: An invitation to the study of food and society*. ISBN 0-415-11424-1, Routledge, London, UK, 272 pp.
10. Alexandratos N. - *World agriculture: Towards 2010 (An FAO study)*. ISBN 92-5-103590-3 (pbk), J. Wiley & Sons, Chichester, UK, 1995, 488 pp.
11. Smil V. - *Feeding the world: A challenge for the twenty-first century*. ISBN 0-262-19432-5, MIT Press, Cambridge, Massachusetts, 2000, 360 pp.
12. Bruinsma J. - *Agriculture: Towards 2015/30, Technical Interim Report, April 2000 (download http://www.fao.org/es/ESD/at2015/toc-e.htm)*. FAO, 2000, 250 pp.
13. Brown L.R. - *Tough choices: Facing the challenge of food scarcity*. ISBN 0-393-31573-8 (pbk), W.W. Norton & Co., New York, 1996, 160 pp.
14. Veerman C.P. - *General introduction*. In: Towards an agenda for agricultural research in Europe (Boekestein A., Diederen P., Jongen W.M.F., Rabbinge

R., Rutten H., eds.), ISBN 90-74134-80-7, Wageningen Pers, Wageningen, 2000, 11-14.

15. Green K., Vieira L., Aiking H. - *Food*. In: Industrial Transformation Science Plan (Vellinga P., Herb N., eds.), IHDP, Bonn (Germany), 1999, 26-33.
16. Weaver P., Jansen L., van Grootveld G., van Spiegel E., Vergragt P. - *Sustainable Technology Development.* ISBN 1874719098, Greenleaf Publishing Ltd, Sheffield (UK), 2000, 304 pp.
17. Bradford E. - *Animal agriculture and global food supply (download http://www.cast-science.org)*.ISBN 1-887383-17-4, Council for Agricultural Science and Technology, Washington, DC, 1999, 92 pp.
18. Aiking H., Vellinga P. - Greening Protein Production and Consumption - The *PROFETAS* Research Programme (Protein Foods, Environment, Technology and Society). Proc. 9th International Greening of Industry Network Conference, Bangkok (Thailand), 21-25 January 2001, 1-10.
19. Aiking H., Vellinga P. - *Environment and food in a changing world: Research issues*. In: Towards an agenda for agricultural research in Europe (Boekestein A., Diederen P., Jongen W.M.F., Rabbinge R., Rutten H., eds.), ISBN 90-74134-80-7, Wageningen Pers, Wageningen, 2000, 199-207.