Available online at www.sciencedirect.com
ScienceDirect
Journal of Cleaner Production 16 (2008) 1138–1141
Journal of Cleaner Production
www.elsevier.com/locate/jclepro

Letter to the editor

Are emissions or wastes consisting of biological nutrients good or healthy?

Abstract

Biological nutrients have been defined as non-hazardous biodegradable materials and products of biodegradation processes. Changes in the concentrations of so-defined biological nutrients have ecological effects and high concentrations may have a negative impact on human health.

This implies that there are no wastes or emissions derived from biological materials, which are ecologically irrelevant. Nor are such wastes intrinsically good or healthy.

Keywords: Wastes; Emissions; Biological nutrients; Healthy; Ecological effects

1. Introduction

Braungart et al. [1] have introduced the concepts of 'healthy emissions' and 'healthy wastes'. 'Healthy wastes are good' they state. The substances that they see as 'healthy' or 'good' are 'biological nutrients'. 'Biological nutrients' are defined as non-hazardous biodegradable materials and products of biodegradation processes [1, p. 1343]. Efficiency in handling 'biological nutrients' is according to Braungart et al. [1] not a virtue, suggesting that emissions or wastes consisting thereof are intrinsically 'good' and 'healthy'. In this context they draw a parallel to the cherry tree, and point out that 'the growth and release of thousands of cherry blossoms, only a few of which become new cherry trees, is a travesty of material intensity per unit of service' [1, p. 1342]. This is not a problem, because 'in nature, all outputs from one process become inputs for another. The concept of waste does not exist' [1, p. 1342].

Braungart et al. [1, p. 1342] apply this view, for example to textile mills. 'If the trimmings from the production of a textile system are composed in such a way that they become nutrients for ecological systems, then it is ecologically irrelevant when they are not included in the saleable product'. 'Even if the material intensity per service unit of the textile mill was astronomically high, the system as a whole would be highly eco-effective because the trimmings would become productive resources for natural systems'.

The proposals for product design of Braungart et al. [1] follow from this point of view. Packaging should consist of 'biological nutrients', which 'when thrown away' support 'the growth of plant life' [1, p. 1343]. Similarly textiles should consist of 'biological nutrients', so that they can 'for example be used as garden mulch' [1, p. 1343].

They also propose to redesign the motorcars as nutrivehicles. Current motorcars aim at reducing the emission of fixed nitrogen (in practice: NO_x); nutrivehicles should rather maximize the production of fixed nitrogen and collect that. After collection, the fixed nitrogen should be used as fertilizer [1, p. 1345].

2. Effects of increased cycling of 'biological nutrients'

The blooms mentioned by Braungart et al. [1], or more in general the 'litter' (blooms, leaves, fruits and branches) derived from the cherry tree, consist of a large variety of substances. These include fixed nitrogen (N) and phosphate, a variety of other minerals such as K, Ca, Mg and Na compounds, metals, such as Zn, Cu and Fe, and carbon compounds. Braungart et al. [1] stress the biodegradability of the latter.

Though plant-derived carbon compounds are in principle biodegradable, not all such compounds are degraded in the environment. They are in practice partially refractory to biodegradation. Such refractory carbon compounds are an important ingredient of soil organic matter, which limits erosion, buffers against fluctuations of soil pH, retains water and is important for soil fertility [2].

Apart from this, it seems useful to look into the design strategy of Braungart et al. [1], by firstly considering the following compounds present in cherry blooms: non-hazardous biodegradable carbon compounds, phosphorus compounds and fixed nitrogen.

0959-6526/$ - see front matter
doi:10.1016/j.jclepro.2008.02.003

Non-hazardous biodegradable compounds are 'biological nutrients' [1, p. 1343]. However, biodegradation may have negative effects. Large inputs of plant-derived biodegradable materials into surface water was in Europe already an environmental problem in the Middle Ages, when wet decomposition ('retting') was practiced to extract fibres from flax and hemp [3]. The high concentrations of plant-derived biodegradable substances led to massive local consumption of oxygen, which was then depleted. This killed water organisms which were dependent on oxygen. Later, discharges from agro-industries, processing plant based materials, caused similar problems on a much larger scale with strong evidence of negative effects on the health of people living in the vicinity of polluted waterways [4]. Though there was cycling of biodegradable material, the increased input in the C cycle was ecologically relevant and had effects which may be considered negative.

Fixed nitrogen (e.g. ammonia and nitrate) and phosphate are present in all organisms and participate in biogeochemical cycling. They become available due to biodegradation of biological materials and are plant nutrients, and may thus be considered biological nutrients [1, p. 1343]. Increased inputs in the nitrogen and phosphorus cycles are, however, ecologically relevant and may have negative effects. Loading water with fixed nitrogen and/or phosphate may lead to 'eutrophication' that alters the species composition of surface waters. Again already in the Middle Ages, European lakes like Lake Steisslingen and the Bodensee showed the disappearance of species native to clear water and the emergence of filamentous algae and phytoplankton that do well in turbid eutrophic waters, showing that changes in fixed nitrogen and/or phosphate may affect species differentially [2,5]. These changes were probably related to agricultural activities and practices such as retting [2,5]. More recently, high levels of phosphate and/or fixed nitrogen nutrients in surface water are infamous for causing 'algal blooms'. Algal blooms cause anaerobic conditions that harm water organisms which are dependent on oxygen and favour a number of organisms that secrete substances that are toxic to humans and other animals [6–10].

Problems with fixed nitrogen are not confined to surface water, but may also occur in ground water. Intensive manuring and storage of manure on sandy soils may lead to high concentrations of nitrate in groundwater that are, on consumption, linked to an increased incidence of illnesses such as stomatitis and methemoglobinemia ('blue baby sickness') [11–13]. Against this background, lowering the emissions of fixed nitrogen and phosphate into surface water and fixed nitrogen in ground water has been advocated (e.g. [6,7,9,10,14]).

Problems with changes in the concentrations of 'biological nutrients' are not confined to water. Eutrophication of surface water has its counterpart in terrestrial eutrophication, mainly by fixed nitrogen compounds [15,16]. Terrestrial eutrophication is associated with losses of plant diversity and may be associated with increased susceptibility of ecosystems to stresses [15,16].

Changes in the biogeochemical N cycle also affect the atmosphere. There are impacts on the ozone layer, tropospheric ozone and climate, which in turn for instance affect human health and crop yields [17–20]. An impact on climate is also linked to the increased concentration of CO_2 which participates in the biogeochemical C cycle. CO_2 is a biological nutrient. It originates in oxidative biodegradation. Without CO_2 plant life would be impossible. Nevertheless, changes in atmospheric concentration may have large differential effects on organisms. Expected increases in CO_2 concentration are predicted to cause local extinctions among a number of extant natural species before 2050 [21] and may be favourable to other species [18]. The expected increases in CO_2 concentration have also been predicted to have substantial effects on human health [18].

At this point, the objection may be raised, that for instance the negative effects of CO_2 outlined here are largely linked to anthropogenic inputs of, what Braungart et al. [1] call, 'technical nutrients': fossil fuels, which should in their view be subjected to eco-effective management. However, similar changes in the CO_2 input in biogeochemical C cycle may be linked to increased consumption of biological nutrients. For instance, substituting fossil fuels by biofuels to power the world economy may have a roughly similar or an even larger effect on atmospheric CO_2 concentration and on climate [22–25].

The examples of the effects of increased emissions of biological nutrients discussed here may be generalized at the level of organisms. Of all compounds that function as nutrients for organisms, there may be too little or too much (see Fig. 1).

What too little or too much is depends on the organism. The amount of a nutrient that is 'healthy' to one organism may be deleterious or fatal to another. Fig. 1 allows for the possibility that there may be actually 'too little' of a biological nutrient. In this case, there may indeed be wastes or emissions that up to a point turn out to be 'healthy' or 'good'.

Switching from motorcars with catalytic converters that convert NO_x into N_2 to nutrivehicles might well be a good thing when there is a shortage of fixed nitrogen in the environment.

However, the amount of fixed nitrogen entering the global biogeochemical N cycle has been subject to a large anthropogenic increase. This in turn has led to large-scale environmental problems, including widespread eutrophication and acidification of aquatic and terrestrial systems an increased greenhouse effect and stratospheric ozone loss [14,15,17,18]. This is a good reason to favour the conversion of NO_x to N_2 [14], and thus an argument against nutrivehicles.

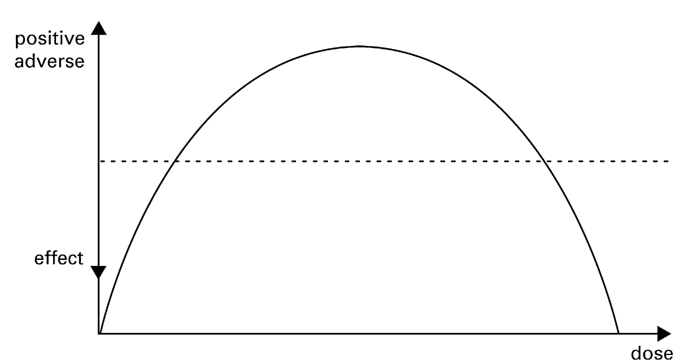

Fig. 1. Generalized picture of the relation between dose of biological nutrient and state ('health') of an organism, showing dose dependent positive (+) and adverse (−) effects.

3. The presence of hazardous substances in biological materials

A second problem with the concept of 'healthy wastes' arises when according to Braungart et al. [1] 'eco-effective' cherry tree (a member of the *Prunus* family) is more closely considered as to the occurrence of substances that may be hazardous to other organisms.

Trees of the *Prunus* family are characterized by the presence of substantial amounts of phenols and cycanogenic glucosides [26–29]. These compounds may be allelopathic substances that, with varying specificity, can be detrimental to other organisms [27,29–31]. Effects on other organisms may for instance show up when applying mulches from *Prunus* derived materials [32] and in graft incompatibility [33]. Allelopathic substances are widespread among plants and micro-organisms and several of them have been developed into commercial pesticides (e.g. [30,31]). The allelopathic substances in turn are a subclass of the larger family of natural toxins produced by plants, animals and micro-organisms, some of which are extremely toxic to humans [34,35].

Also wood of the cherry tree may currently reflect the emission of what Braungart et al. [1] call 'technical nutrients'. Such wood may for instance have elevated contents of heavy metals, which in turn may necessitate restrictions in handling wood derived wastes [36,37].

4. Conclusion

Contrary to what Braungart et al. suggest [1, p. 1342] increased emissions or wastes consisting of 'biological nutrients' are not ecologically irrelevant. That 'biological nutrients' participate in cyclical flows (biogeochemical cycles) does not mean that there are no negative effects of increased inputs in those cycles.

Both the occurrence of negative effects due to increased emissions of 'biological nutrients' and the occurrence of hazardous substances in biological materials suggest that there is often a case for management of natural materials in a way that tries to minimize negative impacts.

All in all, it would seem impossible to consider emissions or wastes containing 'biological nutrients' as intrinsically 'healthy' or 'good'.

References

[1] Braungart M, McDonough W, Bollinger A. Cradle-to-cradle design creating healthy emissions – a strategy for eco-effective product and system design. Journal of Cleaner Production 2007;15:1337–48.
[2] Lal R. Soil carbon sequestration to mitigate climate change. Geoderma 2004;123:1–22.
[3] Hoffmann RC. Economic development and aquatic ecosystems in medieval Europe. The American Historical Review 1996;101:631–69.
[4] Massard-Guilbaud G, Bernardt C. The modern demon. Pollution in urban and industrial Europe. Clermont-Ferrand, France: Presses Universitaires Blaise; 2002.
[5] Eusterhues K, Lechterbeck J, Schneider J, Wolf-Brozio U. Late and post-glacial evolution of Lake Steisslingen (I). Sedimentary history, palynological record and inorganic geochemical indicators. Palaeogeography, Palaeoclimatology, Palaeoecology 2007;187:341–71.
[6] Dagg MJ, Breed GA. Biological effects of Mississippi river nitrogen on the northern Gulf of Mexico. Journal of Marine Systems 2003;43:133–52.
[7] Chambers PA, Dale AR, Scrimgeour GJ, Bothwell ML. Nutrient enrichment of northern rivers in response to pulp mill and municipal discharges. Journal of Aquatic Ecosystem Stress and Recovery 2000;8:53–66.
[8] Heil CA, Glibert PM, Fan C. *Prorocentrum minimum* (Pavillard) Schille. A review of a harmful algal bloom species of growing worldwide importance. Harmful Algae 2005;(4)::449–70.
[9] Mee L. The Black Sea in crisis: a need for concerted international action. Ambio 1992;21:278–86.
[10] Holcomb RW. Waste-water treatment: the tide is turning. Science 1970;169:457–9.
[11] Ritter WF, Chirnside EM. Influence of agricultural practice on nitrates in the water table aquifer. Biological Wastes 1987;19:165–78.
[12] Gupta SK, Gupta RC, Seth AK, Gupta AB, Tech M, Bassin JK, et al. Epidemiological evaluation of recurrent stomatitis, nitrates in drinking water and cytochrome b_5 reductase activity. The American Journal of Gastroenterology 1999;94:1808–12.
[13] Oenema O, Boers PCM, van Eerdt MM, Fraters B, van der Meer HG, Roest CJW, et al. Leaching of nitrate from agriculture to groundwater: the effect of policies and measures in the Netherlands. Environmental Pollution 1998;102:471–6.
[14] Galloway JN, Aber JD, Erisman JW, Seitzinger SR, Howarth RW, Cowling EB, et al. The nitrogen cascade. Bioscience 2003;53:341–55.
[15] Smith VH, Tilman GD, Nekola JC. Eutrophication impacts of excess nutrient inputs on freshwater, marine, terrestrial ecosystems. Environmental Pollution 1999;100:179–96.
[16] Boxman AW, van der Ven PJM, Roelofs JGM. Ecosystem recovery after a decrease in nitrogen input to a Scots pine stand at Ysselsteyn, the Netherlands. Forest Ecology and Management 1998;101:155–63.
[17] Gruber N, Galloway JN. An earth-system perspective of the global nitrogen cycle. Nature 2008;451:293–6.
[18] Intergovernmental Panel on Climate Change (IPCC). Fourth assessment report. Climate change. Cambridge: Cambridge University Press; 2007. summary at www.ipcc.ch.
[19] Moshammer H, Bartonova A, Hanke W, van den Hazel P, Koppe JG, Krämer U, et al. Air pollution: a threat to the health of our children. Acta Pediatrica 2006;453(Suppl. 95):93–105.
[20] Mauzerall DL, Wang X. Protecting agricultural crops from the effects of tropospheric ozone exposure: reconciling science and standard setting in the United States, Europe and Asia. Annual Review of Energy and the Environment 2001;26:237–68.
[21] Thomas CD, Cameron A, Green RE, Bakkenes M, Beaumont LJ, Collingham YC, et al. Extinction risk from climate change. Nature 2004;427:145–8.
[22] Righelato R, Spracklen DV. Carbon mitigation by biofuels or by saving and restoring forests. Science 2007;317:902.
[23] Reijnders L, Huijbregts MAJ. Life cycle greenhouse gas emissions, fossil fuel demand and solar energy conversion efficiency in European bioethanol production for automotive purposes. Journal of Cleaner Production 2007;15:1806–12.
[24] Reijnders L, Huijbregts MAJ. Palm oil and the emission of carbon based greenhouse gases. Journal of Cleaner Production 2008;16:477–82.
[25] Reijnders L, Huijbregts MAJ. Biogenic greenhouse gas emissions linked to the life cycles of biodiesel derived from European rapeseed and Brazilian soybeans. Journal of Cleaner Production, in press.
[26] Peterson SC, Johnson ND, LeGuyader JL. Defensive regurgitation of allelochemicals derived by host cyanogenesis by eastern tent caterpillars. Ecology 1987;68:1268–72.
[27] Stewart KM. The African cherry (*Prunus africana*): can lessons be learned from an over-exploited medicinal tree. Journal of Ethnopharmacology 2003;89:3–13.
[28] Daniel O, Meier MS, Schlatter J, Frischknecht P. Selected phenolic compounds in cultivated plants: ecologic functions, health implications and modulation by pesticides. Environmental Health Perspectives 1999;1(Suppl. 107):109–14.

[29] Singh RP, Nie X, Singh M, Coffin R, Duplessis P. Sodium sulphite inhibition of potato and cherry polyphenolics in nucleic acid extraction for virus detection by RT-PCR. Journal of Virological Methods 2002;99: 123–31.
[30] Singh HP, Batish DR, Kohli RK. Allelopathic interactions and allelochemicals: new possibilities for sustainable weed management. Critical Reviews in Plant Sciences 2003;22:239–311.
[31] Bhowmik PC, Inderjit. Challenges and opportunities in implementing allelopathy for natural weed management. Crop Protection 2003;22:661–71.
[32] Duryea ML, English RJ, Hermansen LA. A comparison of landscape mulches: chemical, allelopathic, decomposition properties. Journal of Arboriculture 1999;25:88–96.
[33] Usenik V, Krska B, Vican M, Stampar F. Early detection of graft incompatibility in apricot (*Prunus armeniaca* L.) using phenol analyses. Scientia Horticulturae 2006;108:332–8.
[34] Pellizzari R, Rossetto O, Washbourne P, Tonello F, Nicotera PL, Montecucco C. In vitro biological activity and toxicity of tetanus and botulinum neurotoxins. Toxicology Letters 1998;102–103:191–7.
[35] Fox CK, Keet CA, Strober JB. Recent advances in infant botulism. Pediatric Neurology 2005;32:149–54.
[36] Pedersen AJ. Characterization and electrodialytic treatment of wood combustion fly ash for the removal of cadmium. Biomass and Bioenergy 2003;25:447–66.
[37] Krook J, Martensson A, Eklund M. Metal contamination in recovered waste wood used as energy source in Sweden. Resources, Conservation and Recycling 2004;41:1–14.

L. Reijnders
IBED/ECDO, University of Amsterdam, Nieuwe Achtergracht 166, NL-1018VW Amsterdam, The Netherlands
Tel.: +31 20 5256269; fax: +31 20 5257431.
E-mail address: l.reijnders@uva.nl

31 January 2008

Available online 25 March 2008