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Summary of temporal trends in pollutant levels observed in marine mammals*

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ABSTRACT

The present paper reviews reported time trends in concentrations and relative abundance of pollutants in marine mammals. Available information refers only to pinnipeds and cetaceans, mainly covers the period 1969-1988 and focuses on DDTs, PCBs and mercury. Although data are limited, there are indications that in the Canadian Arctic, mercury levels in marine mammals have increased in recent decades. By contrast, during the late 1970s and the 1980s, concentrations of DDTs and PCBs in marine mammals from highly polluted areas have tended to decrease. While this trend is likely to continue for DDTs in the future, it is foreseen that until at least the first decades of the next century, PCB levels will stabilise as degradation is compensated by new inputs caused by the recycling of the fraction currently present in non-marine compartments.

KEYWORDS: REVIEW; TRENDS; POLLUTION-METALS; POLLUTION- ORGANOCHLORINE; POLLUTION-PESTICIDES; CETACEANS-GENERAL; PINNIPEDS

INTRODUCTION

The history of the production, use and release into the environment of the different chemicals now considered as pollutants is complex and extremely variable from one compound to another. This fact, together with their different persistence and dispersal rates, makes it extremely difficult to assess historic time trends as well as to predict future trends in the level of exposure of cetaceans to these compounds. For synthetic chemicals such as organochlorines and organobrominates, it is obvious that present concentrations are higher than in preindustrial times, although variations over time in recent years are not easy to determine. In the case of trace elements, radionuclides and polyaromatic hydrocarbons, compounds that are also naturally occurring, there is some controversy as to whether the levels detected in the environment today have always been there. The general opinion is that pre-industrial levels were lower and that an increasing temporal trend is superimposed on the geochemical baseline levels (Wagemann *et al.*, 1990).

It is the intention of this summary paper to delineate observed trends in pollutant levels in marine mammals to assess probable future trends on a global scale.

HISTORIC TRENDS

For synthetic chemicals, there is a paucity of data on levels in pre-industrial or early industrial times. This is largely due to the fact that most compounds of this type presently found in marine mammals were only introduced in the 1930s or later.

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In the case of trace elements, the situation is different. Glacial records show that heavy metals have been in the marine environment since prehistoric times (Murozumi *et al.*, 1969; Weiss *et al.*, 1971). The natural cycling of mercury for example, has usually exceeded that of anthropogenic origin. For this reason, in many cases, trace element tissue concentrations in wildlife can be assumed to be natural, with the exception of certain localised cases, mainly in enclosed seas or riverine systems However, diverse sources, ranging from geological registers and the composition of polar ice to historic autopsy studies, suggest that the levels of exposure to at least some heavy metals may have increased markedly in modern times This holds particularly for concentrations of mercury, lead and cadmium, which have increased since the beginning of the present century in both marine mammals and man (Wagemann *et al.*, 1990). A noteable example is the increase in the lead content of Greenland ice, which is today 200-times that considered 'natural' some thousand years ago (Goyer, 1991).

TRENDS SINCE 1965 AND PROSPECTS

Table 1 summarises our literature survey of pollutant trends observed in marine mammals (usually refereed publications have been considered and the results as presented by the authors have been considered to be valid). About 60% ot the studies refer to Pinnipedia and the rest to Cetacea. The period covered ranges from 1965 to 1994, although most data correspond to the period 1969-1988. The apparent decrease in information after 1988 may reflect the time-lag for publication of more recent surveys. Almost all information is for the Northern Hemisphere. Only two surveys (bottlenose dolphins and common dolphins in South Africa) were carried out during the period 1980-1987 in the Southern Hemisphere.

Data on pollutants other than PCBs and tDDT are insufficient to evaluate trends on a global scale. However, an interesting example of a local trend is the increase in liver mercury levels reported for white whales in the western and eastern Canadian Arctic between the early 1980s and 1994, in ringed seals in the western Canadian Arctic and in narwhals in the eastern Canadian Arctic (Wagemann *et al.*, 1996). Apparently, there was no temporal change in cadmium levels in these species during this period.

Results for PCBs and tDDT for the period prior to 1977 are highly variable and include increases in some areas, although in most cases no significant trends were observed.

Since 1977, all studies have reported either no trend or a decrease in tissue pollutant levels. This may point to a continuing reduction of exposure to contaminants in most marine mammal populations. In relative terms, a decrease in concentrations was first noticed for DDT and later for PCBs, a fact which is consistent with the history of the production, use and restriction of these two groups of organochlorine compounds and their persistence in the ecosystem (de Voogt and Brinkman, 1989; Peterle, 1991). The decrease in DDT levels caused by the discontinuation in its use in pesticides has been associated in many areas with a parallel increase in the relative abundance of its metabolised forms. This has led to the use of various ratios between metabolised and parental compounds of DDT, to assess the time passed since the last inputs of the pesticide were introduced into the ecosystem. In particular, during the 1970s and 1980s, the ratio DDE/tDDT was found to progressively rise in odontocetes and pinnipeds in the North Atlantic (Aguilar, 1984) and in grey and harp seals from eastern Canada (Addison *et al.*, 1984). The decrease of PCBs was particularly apparent in areas close to sources such as Lake Ontario, the Baltic Sea, the Wadden Sea and the North Sea (OECD, 1980; Addison *et al.*, 1986; Olsson and Reutergård, 1986; Reijnders, 1996a). However, concentrations in marine biota from the Baltic and the North Seas levelled off in the 1980s (de Boer, 1988; 1994; Bignert *et al.*, 1993) and similar observations were made by Norstrom *et al.* (1988) for polar bears in the Canadian Arctic, and by Tanabe *et al.* (1994b)

Table 1(a)

Temporal trends in pollutant levels in pinnipeds. i: increase, d: decrease, nt: no trend.

Area	Species	Period	PCB	tDDT	HCB	HCHs	Diel	Hg	Reference
BALTIC									
Baltic Sea	*H. grypus*	1969-88	nt	d					Blomkvist *et al.*,1992; Olsson *et al.*,1994
Aland Sea	*H. grypus*	1970, 1971-72, 1973	nt	nt					Olsson *et al.*,1974
Baltic Sea	*P. hispida*	1969, 1973-80, 1988	d	d					Blomkvist *et al.*,1992; Olsson *et al.*,1994
Gulf of Bothnia	*P. hispida*	1969, 1971-72, 1973	nt	nt					Olsson *et al.*,1974
Gulf of Bothnia	*P. hispida*	1972-77	i	nt					Helle,1981
Gulf of Bothnia	*P. hispida*	1977-80	d	d					Helle,1981
Gulf of Bothnia	*P. hispida*	1980-83	nt	nt					Helle and Stenman, 1984
Lake Saimaa	*P. hispida*	1970-1977, 1981	d	d					Helle *et al.*.,1983
Gulf of Finland	*P. hispida*	1977, 1980-83	d	d					Helle *et al.*,1985
NORTH SEA									
Farne Islands	*H. grypus*	1968-75	nt	d					Holden,1978
Scottish coast	*H. grypus*	1965-71	nt	d			d		Holden,1975
Dutch coast	*P. vitulina*	1973-81	d						Van der Zande and de Ruiter,1983
Dutch coast	*P. vitulina*	1969, 1970-75, 1976						nt	Koeman *et al.*,1972; Reijnders,1980
Dutch coast	*P. vitulina*	1973, 1975-88	d						Reijnders,1980; Reijnders,1996a
E. CANADA									
Sable Island	*H. grypus*	1974, 1976-82	nt	d					Addison *et al.*,1984
North Baffin	*P. hispida*	1972, 1976-84	d	d		nt	nt		Muir *et al.*,1988
St Lawrence Gulf	*P. groenlandicus*	1971-73	d	d			nt		Jones *et al.*,1976
St Lawrence Gulf	*P. groenlandicus*	1971-78	d	d			i		Ronald *et al.*,1984
St Lawrence Gulf	*P. groenlandicus*	1971-82	nt	d					Addison *et al.*,1984
St Lawrence Gulf	*P. groenlandicus*	1982-89	d	nt					Beck *et al.*,1993
NORTHEAST USA									
New York	*P. vitulina*	1980-90, 1992	d	d (DDE)	nt			nt	Lake *et al.*,1995
CANADIAN ARCTIC									
Holman Island	*P. hispida*	1972-81	d	d					Addison *et al.*,1986
Western Arctic	*P. hispida*	1987-93						i	Wagemann *et al.*,1996
Eastern Arctic	*P. hispida*	1989-94						nt	Wagemann *et al.*,1996
N. NORTH PACIFIC									
Japan	*C. ursinus*	1971-76	i	i		i			Tanabe *et al.*,1994b
Japan	*C. ursinus*	1976-88	d	d		d			Tanabe *et al.*,1994b

Table 1(b)

Temporal trends in pollutant levels in cetaceans. i: increase, d: decrease, nt: no trend.

Area	Species	Period	PCB	tDDT	HCB	HCHs	Diel	Hg	Reference
E. CANADA									
W. Hudson Bay	*D. leucas*	1966, 1967-86	nt	d	nt	i			Muir *et al.* (1990)
Bay of Fundy	*P. phocoena*	1969-73		d					Gaskin *et al.* (1982)
Bay of Fundy	*P. phocoena*	1971-77	nt						Gaskin *et al.* (1983)
Bay of Fundy	*P. phocoena*	1969-73						d	Gaskin *et al.* (1979)
Bay of Fundy	*P. phocoena*	1974-77						i	Gaskin *et al.* (1979)
CANADIAN ARCTIC									
Western Arctic	*D. leucas*	1981, 1984-93, 1994						i	Wagemann *et al.* (1996)
Eastern Arctic	*D. leucas*	1984-93, 1994						i	Wagemann *et al.* (1996)
Western Arctic	*M. monoceros*	1978, 1979- 92, 1994						i	Wagemann *et al.* (1996)
N. NORTH PACIFIC									
Japan	*S. coeruleoalba*	1978, 1979-86	nt	nt	d	d			Loganathan *et al.* (1990)
SOUTHERN AFRICA									
East coast	*T. truncatus*	1980, 1983-84, 1987	nt	nt			nt		Cockroft *et al.* (1989)
East coast	*T. truncatus*	1980-87	nt	d					Kock *et al.* (1994)
East coast	*D. delphis*	1980-85	nt	nt					Kock *et al.* (1994)
MEDITERRANEAN									
N.W. coast	*S. coeruleoalba*	1987-94	d	d					Borrell *et al.* (1996)
NORTH SEA									
Scottish coast	*P. phocoena*	1965-71	nt	nt			d		Holden (1975)
ANTARCTIC									
	B. acutorostrata	1984-91	i	nt	nt	nt			Tanabe *et al.* (1995)

for northern fur seals in the Pacific. Apart from the apparent levelling off of the decrease of PCBs in local populations, Tanabe (1988) concluded that the global PCB levels are unlikely to decline in the near future due to the fact that only 30% of all the PCBs produced have been dispersed into the environment. In this context, we can also consider the estimation of Bletchly (1984), that disposal of PCBs will peak at the end of the 1990s.

With respect to future trends in levels in marine mammals, Tateya *et al.* (1988) predicted, based on studies in striped dolphins, that levels of PCBs in marine mammals would be at their highest between 2000 and 2030.

Given the fact that of the *ca* 2,000,000 tonnes of PCBs produced, only 1% has reached the ocean (Reijnders, 1996b), slow dispersal will continue and it is expected that on a global scale, no apparent reduction in the exposure of marine mammals to PCBs will occur until the turn of the 21st century.

In view of the presumed global change in the distribution of organochlorine residue levels, the Arctic waters and adjacent seas and oceans are expected to become the major sink for these contaminants (Tatsukawa, 1993). This holds to a much lesser extent for the Southern Hemisphere (Tanabe *et al.*, 1994a). It is important that monitoring programmes for pollutant trends in marine mammals take this into account.

REFERENCES

Addison, R.F., Brodie, P.F. and Zinck, M.E. 1984. DDT has declined more than PCBs in eastern Canadian seals during the 1970s. *Environ. Sci. Technol.* 18:935–7.

Addison, R.F., Zinck, M.E. and Smith, T.G. 1986. PCBs have declined more than DDT-group residues in Arctic ringed seals, *Phoca hispida*, between 1972 and 1981. *Environ. Sci. Technol.* 20:253–6.

Aguilar, A. 1984. Relationship of DDE/tDDT in marine mammals to the chronology of DDT input into the ecosystem. *Can. J. Fish. Aquat. Sci.* 41:840–4.

Beck, G.G., Smith, T.G. and Addison, R.F. 1993. Organochlorine residues in harp seals, *Phoca groenlandica*, from the Gulf of St. Lawrence and Hudson Strait: an evaluation of contaminant concentrations and burdens. *Can. J. Zool.* 72:174–82.

Bignert, A., Göthberg, A., Jensen, S., Litzen, K., Odsjö, T., Olsson, M. and Reutergård, L. 1993. The need for adequate biological sampling in ecotoxicological investigations: a retrospective study of twenty years pollution monitoring. *Sci. Total Environ.* 128:121–39.

Bletchly, J.D. 1984. Polychlorinated biphenyls: production, current use and possible rate of future disposal in OECD member countries. pp. 343–79. *In:* M.C. Barros, H. Könemann and R. Visser (eds.) *Proceedings of PCB Seminar.* Ministry of Housing, Physical Planning and Environment, The Hague, The Netherlands.

Blomkvist, G., Roos, A., Jensen, S., Bignert, A. and Olsson, M. 1992. Concentrations of DDT and PCB in seals from Swedish and Scottish waters. *Ambio* 21(8):539–45.

de Boer, J. 1988. Trends in chlorobiphenyl contents in livers of Atlantic cod (*Gadus morhua*) from the North Sea, 1979–1987. *Chemosphere* 17:1811–9.

de Boer, J. 1994. Spatial differences and temporal trends of bioaccumulating halogenated hydrocarbons in livers of Atlantic cod (*Gadus morhua*) from the North Sea, 1977–1992. Proceedings Quality Status Report – Scientific Symposium, Ebeltoft, Denmark, April 1994.

Borrell, A., Aguilar, A. and Pastor, T. 1996. Organochlorine compound levels in striped dolphins from the western Mediterranean during the period 1987–1993. *Eur. Res. Cetaceans* [Abstracts] 10:281–5.

Cockcroft, V.G., De Kock, A.C., Lord, D.A. and Ross, G.J.B. 1989. Organochlorines in bottlenose dolphins, *Tursiops truncatus*, from the east coast of South Africa. *S. Afr. J. Mar. Sci.* 8:207–17.

Gaskin, D.E., Stonefield, K.I., Suda, P. and Frank, R. 1979. Changes in mercury levels in Harbor porpoises from the Bay of Fundy, Canada and adjacent waters during 1969–1977. *Arch. Environ. Contam. Toxicol.* 8:733–62.

Gaskin, D.E., Holdrinet, M. and Frank, R. 1982. DDT residues in blubber of harbour porpoise *Phocoena phocoena (L)* from Eastern Canadian waters during the five year period 1969-1973. *FAO Fish. Ser. (5) [Mammals in the Seas]* 4:135–43.

Gaskin, D.E., Frank, R. and Holdrinet, M. 1983. Polychlorinated biphenyls in harbour porpoises, *Phocoena phocoena* (L.) from the Bay of Fundy, Canada and adjacent waters, with some information on chlordane and hexachlorobenzene levels. *Arch. Environ. Contam. Toxicol.* 12:211–9.

Goyer, R.A. 1991. Toxic effects of metals. pp. 623-80. *In:* M.O. Ambur, J. Doull and C.D. Klaassen (eds.) *Toxicology. The Basic Science of Poisons.* 4th. Edn. McGraw-Hill Inc. New York. 1033pp.

Helle, E. 1981. Reproductive trends and occurrence of organochlorines and heavy metals in the Baltic seal populations. Paper 1981/E:37 presented to the ICES Marine Mammal Committee (unpublished). 9pp.

Helle, E. and Stenman, O. 1984. Recent trends in levels of PCBs and DDT compounds in seals from the Finnish waters of the Baltic sea. ICES. C.M. 1984/E:43. 8pp.

Helle, E., Hyvärinen, H., Pyysalo, H. and Wickström, K. 1983. Levels of organochlorine compounds in an inland seal population in eastern Finland. *Mar. Pollut. Bull.* 14(7):256–60.

Helle, E., Hyvärinen, H., and Stenman, O. 1985. PCB and DDT levels in the Baltic and Saimaa seal populations. *Finn. Game Res.* 44:63–8.

Holden, A.V. 1975. The accumulation of oceanic contaminants in marine mammals. *Rapp. P-V Réun. Cons. Int. Explor. Mer.* 169:353–61.

Holden, A V. 1978. Organochlorine residues in blubber of grey seals (*Halichoerus grypus*) from the Farne islands. ICES. C.M. 1978/E:41. 5pp.

Jones, D., Ronald, K., Lavigne, D.M., Frank, R., Holdrinet, M. and Uthe, J.F. 1976. Organochlorine and mercury residues in the harp seal (*Pagophilus groenlandicus*). *Sci. Total Environ.* 5:181–95.

de Kock, A.C., Best, P.B., Cockcroft, V. and Bosma, C. 1994. Persistent organochlorine residues in small cetaceans from the east and west coasts of southern Africa. *Sci. Total Environ.* 154:153–62.

Koeman, J.H., Peeters, W.H.M., Smit, C.J., Tjioe, P.S. and de Goey, J.J.M. 1972. Persistant chemicals in marine mammals. *TNO-Nieuws* 27:570–8.

Lake, C.A., Lake, J.L., Haebler, R., McKinney, R., Boothman, W.S and Sadove, S.S. 1995. Contaminant levels in harbor seals from the northeastern United States. *Arch. Environ. Contam. Toxicol.* 29:128-34.

Loganathan, B.G., Tanabe, S., Tanaka, H., Watanabe, S., Miyazaki, N., Amano, M. and Tatsukawa, R. 1990. Comparison of organochlorine residue levels in the striped dolphin from western North Pacific, 1978-79 and 1986. *Mar. Pollut. Bull.* 21(9):435–9.

Muir, D.C.G., Simon, M. and Norstrom, R.J. 1988. Organochlorine contaminants in Arctic marine food chains - accumulation of specific polychlorinated biphenyls and chlordane-related compounds. *Environ. Sci. Technol.* 22(9):1071–9.

Muir, D.C.G., Ford, C.A., Stewart, R.E.A., Smith, T.G., Addison, R.F., Zinck, M.E. and Beland, P. 1990. Organochlorine contaminants in belugas, *Delphinapterus leucas*, from Canadian waters. *Can. Bull. Fish. Aquat. Sci.* 224:165–90.

Murozumi, M., Chow, T.J. and Petterson, C. 1969. Chemical concentrations of pollutant lead aerosols, terrestrial dusts and sea salts in Greenland and Antarctic snow strata. *Geochim. Cosmochim. Acta* 33:1247–94.

Norstrom, R.J., Simon, M., Muir, D.C.G. and Schweinsburg, R.E. 1988. Organochlorine contaminants in Arctic marine food chains: identification, geographical distribution and temporal trends in polar bears. *Environ. Sci. Technol.* 22:1063–71.

OECD. 1980. Chemical trends in wildlife: an international cooperative study. OECD sales No. 700 DH 97 80 06 01.

Olsson, M. and Reutergård, L. 1986. DDT and PCB pollution trends in the Swedish aquatic environment. *Ambio.* 15(9):103–9.

Olsson, M., Johnels, A.G. and Vaz, R. 1974. DDT and PCB levels in seals from Swedish waters. pp. 43–65. *In:* Proc. Symp. on the Seal in the Baltic, 4–6 June. Lidingo, Sweden.

Olsson, M., Karlsson, B. and Ahnland, E. 1994. Diseases and environmental contaminants in seals from the Baltic and the Swedish west coast. *Sci. Total Environ.* 154:217–27.

Peterle, T.J. 1991. *Wildlife Toxicology*. Van Nostrand Reinhold, New York. 322pp.

Reijnders, P.J.H. 1980. Organochlorine and heavy metal residues in harbour seals from the Wadden Sea and their possible effect on reproduction. *Neth. J. Sea Res.* 14:30–65.

Reijnders, P.J.H. 1996a. Developments of grey and harbour seal populations in the international Wadden Sea: reorientation on management and related research. *Wadden Sea News Letter* 1996 2:12–6.

Reijnders, P.J.H. 1996b. Organohalogen and heavy metal contamination in cetaceans: observed effects, potential impact and future prospects. pp. 205–17. *In:* M.P. Simmonds and J.D. Hutchinson (eds.) *The Conservation of Whales and Dolphins: Science and Practice*. John Wiley and Sons Ltd, Chichester, England. 476pp.

Ronald, K., Frank, R.J., Dougan, J.L., Frank, R. and Braun, H.E. 1984. Pollutants in harp seals (*Phoca groenlandica*) I. Organochlorines. *Sci. Total Environ.* 38:133–52.

Tanabe, S. 1988. PCB problems in the future: foresight from current knowledge. *Environ. Pollut.* 50:5–28.

Tanabe, S., Iwata, H. and Tatsukawa, R. 1994a. Global contamination by persistent organochlorines and their ecotoxicological impact on marine mammals. *Sci. Total Environ.* 154:163–77.

Tanabe, S., Sung, J.-K., Choi, D.-Y., Baba, N., Kiyota, M., Yoshida, K. and Tatsukawa, R. 1994b. Persistent organochlorine residues in northern fur seals from the Pacific coast of Japan since 1971. *Environ. Pollut.* 85:305–14.

Tanabe, S., Aono, S., Fujise, Y., Kato, H. and Tatsukawa, R. 1995. Persistent organochlorine residues in the Antarctic minke whale, *Balaenoptera acutorostrata*. Paper SC/M95/P13 presented to the Workshop on Chemical Pollution and Cetaceans, Bergen, Norway. March 1995 (unpublished). 6pp.

Tateya, S., Tanabe, S. and Tatsukawa, R. 1988. PCBs on the globe: possible trend of future levels in the open ocean environment. pp. 237–81. *In:* N.W. Schmidtke (ed.) *Toxic Contaminants in Large Lakes*. Proceedings World Conference on Large Lakes. May 1986, Mackinac Island, Michigan, USA. Lewis Publishers, Inc.

Tatsukawa, R. 1993. Overview of marine pollution. pp. 14–5. *In:* N. Myazaki (ed.) Abstracts International Symposium Marine Pollution – Mammals and Toxic Contaminants. 6–8 February 1993. Kamogawa, Japan.

de Voogt, P. and Brinkman, U.A.T. 1989. Production, properties and usage of polychlorinated biphenyls. pp. 3–45. *In:* R. D. Kimbrough and A.A. Jensen (eds.) *Halogenated Biphenyls, Terphenyls, Naphthalenes, Dibenzodioxins and Related Products*. Elsevier, Amsterdam.

Wagemann, R., Stewart, R.E.A., Beland, P. and Desjardins, C. 1990. Heavy metals and selenium in tissues of beluga whales, *Delphinapterus leucas*, from the Canadian Arctic and the St Lawrence Estuary. pp. 191–206. *In:* T.G. Smith. D.J. St Aubin and J.R. Geraci (eds.) *Can. Bull. Fish Aquat. Sci.* 224. Advances in Research on the Beluga Whale, *Delphinapterus leucas*.

Wagemann, R., Innes, S. and Richard, P. R. 1996. Overview and regional and temporal differences of heavy metals in Arctic whales and ringed seals in the Canadian Arctic. *Sci. Total Environ.* 186:41–66.

Weiss, H.V., Koide, M. and Goldberg, E.D. 1971. Mercury in a Greenland icesheet: evidence of recent input by man. *Science* 174:692–4.

van der Zande, T. and de Ruiter, E. 1983. The quantification of technical mixtures of PCBs by microwave plasma detection and the analysis of PCBs in the blubber lipid from harbour seals (*Phoca vitulina*). *Sci. Total Environ.* 27:113–47.