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Infant and Young Child Feeding and Chemical Residues

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"Given that breastfeeding reduces child mortality and has benefits that extend into adulthood, every effort has been made to protect, promote and support breastfeeding in the context of these studies […] Human milk - though still the best food for infants - has been unintentionally compromised by unwelcome chemicals from our environment, as a result of eating, drinking and living in a technologically advanced, but polluted, world. However, the mere presence of an environmental chemical in human milk does not necessarily indicate that a serious health risk exists for breastfed infants. Few, if any, adverse effects have been documented as associated solely with consumption of human milk containing background levels of environmental chemicals, and none have been clinically or epidemiologically demonstrated. Only in very rare situations involving high levels of pollution have effects on infants occurred through human milk consumption. In contrast, epidemiological studies have demonstrated that human milk and the practice of breastfeeding confer significant measurable health benefits to infants and to nursing mothers."[2]

Introduction

Parents, caregivers and health professionals are rightly concerned about feeding infants and young children in our polluted world. The repeated failure of systems aiming to protect the safety of children's food and the undue presence of toxic substances and chemical residues in numerous foods have harmful effects on children's health. In this context, parents, caregivers and health professionals need objective and independent information on the risks and dangers of environmental pollution. This information has to cover a broad spectrum of issues. Focussing on the presence of chemical residues in breastmilk without examining the nutrition and health of the whole family and the environment in which the family lives, as the media often tends to do, is akin to focussing on the ill health of a single tree in a forest without examining the health of the whole forest and of the environment in which it is growing. Also, when giving information and advice to individual families, one has to consider not only the practical aspects of present decisions and behaviours, but also the impact these may have on future generations. It is with this perspective in mind that IBFAN issued in April 2013 a revised *Statement on Infant and Young Child Feeding and Chemical Residues*.[3] This issue of *Breastfeeding Briefs* expands on that statement; it covers the main chemical residues found in breastmilk as well as those found in infant formula, baby foods, feeding bottles and teats. It also emphasizes the potential for harm to health and development caused by chemical exposure during pregnancy, at a time when the tissues and organs of the unborn child are developing rapidly. Lastly, it considers the role of breastfeeding in mitigating these harmful effects. Contrary to breastfeeding, formula feeding does not afford any protection to babies exposed to chemicals in the womb. In addition, it contributes to environmental

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[2] Fourth WHO-Coordinated Survey of Human Milk for Persistent Organic Pollutants in cooperation with UNEP. Guidelines for Developing a National Protocol. Revised 1 October 2007.

[3] http://www.ibfan.org/IBFAN-Statement-on-IYCF.pdf

pollution that will eventually increase the risk of exposure of us all, and of women during pregnancy and lactation, to chemicals. Moreover, it has a negative ecological footprint with consequences for future generations that are aggravated if breastfeeding is discouraged whenever chemical residues are detected in breastmilk.

Chemical residues

All chemical residues found in humans and wildlife are xenobiotics[4] manufactured by industry, or pollutants dispersed into the biosphere, which eventually end up in the food chains. These chemicals constitute the "body burden" that is measured in all human beings, both men and women. Every human body is estimated to contain up to 200 man-made chemicals.[5] Most of these chemicals find their way into the food chain and are thus absorbed by humans; they may also be absorbed through the skin and the respiratory system. Many compounds are persistent and accumulate in organisms as these move higher up the food chain, progressively increasing their concentration. Some of these toxic compounds, dioxins among them, are extremely persistent in our bodies and in the environment, and it may take several decades to get rid of them. Most compounds are fat soluble, meaning that they dissolve and tend to concentrate in body fat; their levels can be measured in many body tissues and fluids (blood, serum, urine, sperm, placenta, umbilical cord blood), but are easier to measure in breastmilk because of its higher fat content and the relative ease with which it can be extracted and analysed. For this reason, breastmilk is generally used to measure the "body burden" of chemicals in human beings and we are often led to believe that it is the breastmilk itself, rather than the whole of our bodies, that is polluted with dangerous man-made chemicals. Indeed, as a result of dramatic media shortcuts and titles, there are numerous examples of scares in the media about "toxic", "poisoned" or "polluted" breastmilk, as, for many years, breastmilk was the only medium used to measure chemical residues in human beings.

Some man-made chemicals are products intended for different purposes: compounds to be used in agriculture (pesticides, fertilizers) or in industry and trade (food packaging, electric and electronic appliances), intermediaries in other chemical processes (production of paints, additives, preservatives), ingredients and additives for other products (gasoline, rocket fuel, cleaning fluids, cosmetics). Others are unintended by-products of specific industrial processes: dioxins and furans, for example, are by-products of various high-temperature procedures used to make steel or cement, or to incinerate waste products.

Effects of chemical residues on health and the environment

Research has shown that chemical residues can have a harmful impact on humans and wildlife. Some are known to cause cancer, some are neurotoxic, some impair the immune and endocrine systems,[6] and some are associated with the development of chronic diseases and may have inter-generational effects on reproduction. Little is known about their cumulative effect and about how they interact in combination with each other in what is called the "toxic cocktail". Many of these compounds act as endocrine disrupting chemicals (EDCs), i.e. they mimic human hormones such as oestrogens. EDCs are particularly dangerous when they act on germ cells,[7] thus possibly interfering with reproduction and the health of future human generations, and endangering our evolution as a species.[8]

Infants and young children are particularly vulnerable to the effects of exposure to chemicals because they are at the most sensitive stages of human development. Prenatal exposure to chemicals, when a baby is in its mother's womb, is of even greater concern than postnatal exposure, when a baby is exposed after birth to residues of chemicals found in breastmilk or to chemicals in formula, baby foods and feeding bottles.

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[4] A xenobiotic is a chemical found in a living organism, but one which is not normally produced or expected in the organism, or which is present in much higher concentrations than usual.

[5] http://www.chemicalbodyburden.org/whatisbb.htm

[6] Hertz-Picciotto I, Youn Park H, Dostal M et al. Prenatal exposures to persistent and non-persistent organic compounds and effects on immune system development. Basic Clin Pharmacol Toxicol 2008;102:146-54

[7] Germ cells are present in the human embryo during the first 6 weeks; they then migrate to the gonads to give rise to spermatozoa and ova. They are the link between generations.

[8] Bergman Å, Heindel JJ, Jobling S, Kidd KA, Thomas Zoeller R (editors). State of the science of endocrine disrupting chemicals 2012. United Nations Environment Programme and the World Health Organization, 2013

Prenatal exposure, especially if it occurs when the stem cells[9] differentiate into cells developing into specific tissues and organs, may bring about harmful changes that can cause diseases later in life.[10] Because the brain starts developing during foetal life, and continues to grow and to develop rapidly after birth and during the first years of life, brain damage due to chemical residues can occur both in the pre- and the post-natal period. Breastmilk contains substances that assist the brain in developing normally after birth. It also contains protective and stimulating agents that help the child develop a strong immune system. Breastfeeding therefore, often mitigates the harmful effects of chemical exposure in the womb or soon after birth.[11]

Unlike breastmilk, formula does not afford any protection or mitigation. First, because formula does not contain the same combination of protective and stimulating substances and therefore does not assist in developing the human brain and immune system. Second, because infant, follow-up and toddler formula, as well as many industrial baby foods, can also contain the same chemical residues found in breastmilk, but often at higher levels.[12] These chemicals are also found in industrial foods for older children and adults. Exposure to some of these substances can also occur through the use of the plastic bottles and cups used to feed these foods and drinks to infants and young children, caused by their transfer to foods and beverages from the polycarbonate plastics of feeding bottles and the epoxy resin lining of tin cans and packages. Third, powdered infant formula can be intrinsically contaminated with dangerous bacteria introduced during the manufacturing process, for example with Cronobacter sakazakii. Once reconstituted, the powdered infant formula can be contaminated by the same and other bacteria because of incorrect preparation, handling and storage. To avoid the severe damage to infant health and development that can be caused by these various forms of bacterial contamination, it is important to follow step-by-step the WHO recommendations for the preparation of powdered infant formula.[13]

In addition to the above points, the mass production of formula and baby foods leaves a heavy carbon footprint and contributes significantly to depleting the natural resources of our environment and to increasing environmental pollution. This is because large amounts of:

- land, water, fertilisers, pesticides and waste are used and produced (often after destroying forests) to develop the dairy industry and for breeding and feeding cows;
- paper, plastics, glass, rubber and raw materials are needed for packaging and marketing;
- water, chemical processes and energy are needed for production and transport;
- water, chemicals and energy as well as raw materials to manufacture utensils are needed for home preparation and administration to infants and children;
- non-biodegradable waste materials are often disposed of by dumping on land or landfill sites, by burning or incinerating, or, in the best of cases and wherever possible, by recycling.

All this is an unnecessary use of scarce resources that contributes to increasing our land, water, raw materials and carbon footprints, with the well-documented - although still controversial - consequences on global warming, climate change, agriculture, food safety, nutrition and health. Moreover, as some of these processes emit dangerous substances into the environment, the decision not to breastfeed because of the chemicals found in breastmilk will, ironically and most probably, lead to an increase in the levels of these chemicals in the environment. In our view, policy-makers should be alerted to the need to legislate in order to reduce the waste and pollution caused by the production, distribution and disposal of non-biodegradable formula and other infant and young child feeding products.

[9] Cells that can differentiate into diverse specialized cell types. In a developing embryo, stem cells can differentiate into all the specialized cells of the various developing organs and tissues, but can also maintain the normal turnover of regenerative tissues, such as blood, skin or intestine.

[10] Soto AM, Vandenberg LN, Maffini MV et al. Does breast cancer start in the womb? Basic Clin Pharmacol Toxicol 2008;102:125-33

[11] LaKind JS, Berlin CM, Mattison DR. The heart of the matter on breastmilk and environmental chemicals: essential points for healthcare providers and new parents. Breastfeed Med 2008;3:251-9

[12] Ljung K, Palm B, Grandér M et al. High concentrations of essential and toxic elements in infant formula and infant foods: a matter of concern. Food Chemistry 2011;127:943-51

[13] http://www.who.int/foodsafety/publications/micro/pif_guidelines.pdf

Implications for breastfeeding

Breastmilk is often cited as containing dioxins and other chemical residues.[14] This is because breastmilk has a high proportion of fat and because fat soluble chemicals are relatively easily measured in it. It is not because breastmilk is any more polluted than other parts of the human body or because residues in breastmilk cause more harm than those found in other parts of the body. In fact, researchers agree that exposure to chemical residues via the placenta is much more dangerous for the health of the newborn than exposure via breastmilk.[15] For example, a high level of transfer of pesticides, PCBs or dioxins during pregnancy can lead to the impairment of foetal and child growth and interfere with the correct development of many tissues and organs, mainly of the psycho-neuro-endocrine and immune systems. However, breastmilk has been shown to mitigate or minimise the effects of some of the damage caused by exposure to these substances during foetal life.[16] As mentioned above, formula feeding has no such protective or mitigating effect on these health risks.

Breastfeeding, even in a polluted environment and after adjusting for varying levels of exposure to chemicals during pregnancy, has such a positive impact on the nutrition, health and development of children that most health authorities recommend that it should be protected, promoted and supported.[17, 18] To this general recommendation, we should add some specific considerations:

- Except in cases of industrial disasters and of exceedingly high levels of dangerous residues after an industrial disaster, the recommendation to protect, promote and support breastfeeding holds true because the benefits of breastfeeding far outweigh any possible harm.[19]
- The debate about reports of chemical residues detected in breastmilk should not unduly influence a mother's decision to not breastfeed.[20]
- Future parents and caregivers of children should be informed of the practical ways to reduce exposure to toxic chemicals (see box on next page).
- We should all campaign to reduce the amount of chemicals in our environment and to counter the powerful lobbies of the plastics and chemical industries.

Finally and most importantly, we must acknowledge the fact that the burden of chemical pollution, as revealed by the presence of residues in breastmilk, has been and is rapidly moving from the high- to the low-income populations of our planet. This is due to two interdependent factors, the redistribution of industry and the weak environmental regulations in the new industrial locations. Bio-monitoring of breastmilk and of other body tissues should be undertaken regularly in all countries and regions affected by the environmental pollution of chemical residues, and mothers and the general public should be informed of the findings in all transparency. Such a process would help to enforce stricter regulations for the protection of the environment and of breastmilk, with the result of eventually benefiting everybody, not only mothers and children. Actions to protect the environment, and from there the food chain and breastmilk, from industrial pollution, are urgently needed in these low-income populations.

The box on the following page indicates some ways of protecting ourselves and our families from exposure to toxic chemicals.

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[14] LaKind JS, Berlin CM, Naiman DQ. Infant exposure to chemicals in breast milk in the United States: what we need to learn from a breast milk monitoring program. Environ Health Perspect 2001;109:75-88

[15] Wigle DT, Arbuckle TE, Turner MC, Bérubé A, Yang Q, Liu S, et al. Epidemiologic evidence of relationships between reproductive and child health outcomes and environmental chemical contaminants. J Toxicol Environ Health B Crit Rev 2008;11:373–517

[16] Ribas-Fito N, Julvez J, Torrent M et al. Beneficial effects of breastfeeding on cognition regardless of DDT concentrations at birth. Am J Epidemiol 2007;166:1198-202

[17] Cattaneo A, Lehners M. Letter published in Environmental Health Perspectives, September 2004: http://www.ibfan.org/prents_corner-residues-more-letter.html

[18] Pronczuk J, Moy G, Vallenas C. Breast Milk: an Optimal Food. Environ Health Perspect 2004;112:A722-23

[19] Mead MN. Contaminants in human milk: weighing the risks against the benefits of breastfeeding. Environ Health Perspect 2008;116:A427-34

[20] Arendt M. Communicating human biomonitoring results to ensure policy coherence with public health recommendations: analysing breastmilk whilst protecting, promoting and supporting breastfeeding. Environ Health 2008;7(Suppl 1):S6

Practical ways to reduce exposure to toxic chemicals:[21]

- Increase the intake of fresh foods, fruit and vegetables in particular, and reduce the intake of fats, especially those of animal origin.
- Thoroughly wash fruit and vegetables before eating them to eliminate chemical residues on their surface.
- As far as possible, give preference to certified organic foods.
- As far as possible, in particular during pregnancy and lactation, avoid eating big fish (e.g., swordfish, tuna, shark) that accumulate chemical residues; give preference to small fish.
- Prevent overweight and obesity; if overweight or obese, do not try to lose weight rapidly in pregnancy and lactation as this will release chemical residues accumulated in fat tissue towards blood and breastmilk.
- Avoid using plastics containing phthalates and bisphenol A; give preference to glass or ceramic containers for foods and drinks.
- Avoid exposure to tobacco smoke, it contains more than 3,500 harmful chemical compounds.
- Avoid substances containing harmful chemical residues for personal care (shampoos, cosmetics), home work (paints, solvents, glues, detergents) or gardening (pesticides), especially during pregnancy and lactation.
- For working women and men of reproductive age, and more specifically working women during pregnancy and lactation, defend the right to work in an environment that is free from chemical residues.

Conclusions

Decision-makers at industry and political levels should adopt environmentally-friendly initiatives for production and waste disposal. They should promote awareness campaigns informing about the ecological dangers. They should develop an appropriate legal framework to prevent the harmful pollution of our environment and to protect the health of our children, both present and future generations. The global application of the Stockholm Convention on Persistent Organic Pollutants (POPs),[22] which bans the production and use of several particularly persistent and toxic compounds, will hopefully lead to a world free of chemical residues. The initial number of banned compounds was 12; this number is periodically revised based on evidence of harmfulness. The strict controls implemented by some countries on the emission of chemical pollutants into the air, soil and water has led to the progressive reduction of their environmental load, as shown by a recent survey coordinated by WHO and UNEP.[23] Such a reduction of pollutants aims for an environment - and breastmilk - totally free of chemical residues. This reduction is also possible in the newly industrialised countries, as long as the right political commitment is stimulated by pressure from citizens, with women and mothers at the front line.

[21] Van Esterik P. Risks, rights and regulation communicating about risks and infant feeding. World Alliance for Breastfeeding Action (WABA). 2002. http://www.waba.org.my/whatwedo/environment/penny.htm

[22] http://www.pops.int/documents/convtext/convtext_en.pdf

[23] UNEP/WHO. Results of the joint Stockholm Convention Secretariat/World Health Organization human milk survey (fourth and fifth rounds). WHO, Geneva, 2011, (UNEP/POPS/COP.5/INF/28)

Detailed information on a few chemical residues

In the following section we provide precise information concerning a number of chemical residues or families of chemical residues. The list is not exhaustive and includes only the substances for which there is ample research literature and that are the target of important policies and regulations worldwide.

Endocrine disruptors (EDCs)

Many of the chemical residues considered in this document act as EDCs. This means that they interfere with the endocrine system and with the effects of the hormones that are responsible for our development, behaviour, fertility, and for the maintenance of normal cell metabolism.[24] Exposure to EDCs has consequences on all human (and animal) tissues that are regulated by hormones. They may affect the reproductive system of males and females, typically with the masculinization of females and the feminization of males, and with alterations of puberty, menstrual cycles and fertility. Exposure to EDCs has been associated with an increased risk of cancers in the reproductive and related organs (testicles, ovaries, breasts, prostate), and with the development of obesity and related disorders later in life.[25] They may affect brain development and cause learning and cognitive disabilities, as well as birth defects. Finally, they may act on germ cells that develop into spermatozoids and eggs, altering their DNA and thus the health of future generations. The younger the person is exposed to EDCs, the more likely and severe the effect; foetal life is thus the most sensitive period, followed by infancy and childhood. Unlike other toxic substances, the effect of EDCs is not dependent on the amount of exposure: even small levels of pollution may interfere with the endocrine system by suppressing, mimicking or altering the hormonal function, and, a fortiori, the embryo-foetal development.

Dioxins and furans

Dioxins and furans are among the most toxic compounds - they are measured in picograms, one trillionth of a gram - and the only effective way of dealing with them is to prevent their production. Acute intoxication can cause death, birth defects and severe damage to several tissues and organs, as brought to public knowledge during the Vietnam War and after industrial accidents, in Italy and Japan for example.[26] Chronic exposure to both these compounds is associated with a higher incidence of many types of cancer, with birth defects and the impairment of mental and neurological development.[27] In addition, dioxins and furans act as EDCs. These two families of chemicals are not produced as such, but are unwillingly produced in very small but dangerous quantities in most combustions (foundries, incineration and burning of waste of chlorinated substances and plastics, the petrol and plastics industries) and in a few chemical processes (production of pesticides and herbicides and the chlorine bleaching of wood pulp), and then released into the atmosphere. From there, as a result of prevailing winds, they can be carried for short or long distances and fall onto the soil or water, where they accumulate and persist for many years. They are then absorbed by plants and animals, and end up in edible products, especially those containing important amounts of fat (some sea foods, milk, cheese). Dioxins and furans enter the human body mainly through the food chain (90-95%), but also by means of the air (5-10%) and by skin contact - especially due to occupational exposure. Mothers may transfer these chemicals to the foetus and the infant through placental blood and breastmilk.[28] Dioxins and furans have been found in infant formula as well, but at lower concentrations than in breastmilk because cow's milk, the main ingredient of infant formula, is usually less polluted than breastmilk, as cows are

[24] Meeker JD. Exposure to environmental endocrine disruptors and child development. Arch Pediatr Adolesc Med 2012;166:1-7

[25] Newbold RR. Developmental exposure to endocrine-disrupting chemicals programs for reproductive tract alterations and obesity later in life. Am J Clin Nutr 2011;94(suppl):1939-42S

[26] The Seveso disaster occurred in Italy in 1976 and resulted in the highest known exposure of a population to dioxins (see http://en.wikipedia.org/wiki/Seveso_disaster); the Minamata disaster occurred in Japan in the 1950s and exposed the population to very high doses of mercury (see http://en.wikipedia.org/wiki/Minamata_disease).

[27] Vreugdenhil HJ, Slijper FM, Mulder PG et al. Effects of perinatal exposure to PCBs and dioxins on play behaviour in Dutch children at school age. Environ Health Perspect 2002;110:A593-8

[28] Harden F, Muller J, Toms L et al. Dioxins in the Australian population: levels in human milk. National Dioxins Program, Technical Report N. 10. Australian Government, Department of the Environment and Heritage, Canberra, 2004

herbivorous and are positioned at a lower level in the food chain.[29] This is not a sufficient reason to replace breastmilk with formula; first, because research has shown that, adjusting for prenatal exposure, babies fed breastmilk containing dioxins still develop better than formula-fed babies;[30] and second, because formula and bottle feeding produce waste that may then be incinerated and result in producing more dioxin, thus maintaining the toxic cycle. It is also important to emphasise that over the past three decades, the levels of dioxins in the environment and in food, including breastmilk and infant formula, have decreased in countries that apply the strict industrial rules of the Stockholm Convention on POPs. This confirms that the alternative is not the replacement of breastmilk, but the prevention of dioxin production.[31]

Polychlorinated biphenyls (PCBs)

PCBs were widely used in electric devices before their production was banned by the United States Congress in 1979 and by the Stockholm Convention on POPs in 2001. However, due to their perdurability and because their disposal is not sufficiently controlled, PCBs are still found in the environment, they continue to enter the food chain, and are therefore still found in cord blood and in breastmilk, most often as the result of the consumption of polluted foods of animal origin. PCBs act as EDCs.[32] Exposure to PCBs in utero and after birth may also lead to low birth weight,[33] and is associated with neurological and developmental disorders (lower IQ, anomalous behaviour, impaired memory), and with immune deficiencies.[34] Traces of PCBs can be found in infant formula, especially certain types such as the so-called "hypoallergenic formula", and in baby foods, although at much lower levels that those reported in some studies on breastmilk.[35] However, since the benefits of breastfeeding far outweigh the possible harmful effects of PCBs, health authorities recommend that in the presence of PCBs, there should be no change to existing advice in support of breastfeeding.

Flame-retardants

These chemicals are widely used in electronics (TV sets, computers, mobile phones), electric appliances, carpets, textiles, furniture, building materials and plastic products, to delay the development of fire and thus reduce damage and burns. Some of them, for example the so-called "polybrominated diphenyl ethers" (PBDEs), are not chemically bound to an object and can therefore be released into the environment and remain in buildings - homes and workplaces for example - and eventually enter the food chain. They can also be inhaled with dust and absorbed through the skin.[36] Flame retardants have been found in animals and humans throughout the world.[37] Their levels in the USA are much higher than in Europe as many more products are treated with them. Flame retardants impair the development of the brain, starting from foetal life, with consequences on motor activity, learning, memory, and social and emotional development.[38] They act also as EDCs. Infants can be exposed in utero, then via breastmilk where these substances can

[29] Pandelova M, Piccinelli R, Kashama S et al. Assessment of dietary exposure to PCDD/F and dioxin-like PCB in infant formulae available on the EU market. Chemosphere 2010;81:1018-21

[30] Boersma ER, Lanting CI. Environmental exposure to polychlorinated biphenyls (PCBs) and dioxins. Consequences for longterm neurological and cognitive development of the child lactation. Adv Exp Med Biol 2000;478:271-87

[31] Malisch R, Kypke K, Kotz A et al. WHO/UNEP-coordinated exposure study (2008-2009) on levels of persistent organic pollutants (POPs) in human milk with regard to the global monitoring plan. Organohalogen Compounds 2010;72:1766-9

[32] Blanck HM, Marcus M, Tolbert PE et al. Age at menarche and Tanner stage in girls exposed in utero and postnatally to polybrominated biphenyl. Epidemiology 2000;11:641-7

[33] Govarts E, Nieuwenhuijsen M, Schoeters G et al. Birth weight and prenatal exposure to polychlorinated biphenyls (PCBs) and dichlorodiphenyldichloroethylene (DDE): a meta-analysis within 12 European birth cohorts. Environ Health Perspect 2012;120:162-70

[34] Weijs PJM, Bakker MI, Korver KR et al. Dioxin and dioxin-like PCB exposure of non-breastfed Dutch infants. Chemosphere 2006;64:1521-5

[35] Pandelova M, Piccinelli R, Kashama S et al. Assessment of dietary exposure to PCDD/F and dioxin-like PCB in infant formulae available on the EU market. Chemosphere 2010;81:1018-21

[36] Sjödin A, Patterson DG Jr, Bergman A. A review on human exposure to brominated flame retardants, particularly polybrominated diphenyl ethers. Environ Int 2003;29:829-39

[37] Frederiksen M, Vorkamp K, Thomsen M et al. Human internal and external exposure to PBDEs: a review of levels and sources. Int J Hyg Environ Health 2009;212:109-34

[38] Costa LG, Giordano G, Tagliaferro S et al. Polybrominated diphenyl ether (PBDE) flame retardants: environmental contamination, human body burden and potential adverse health effects. Acta Biomed 2008;79:172-83

concentrate as they are lipophilic.[39] They can be found in other foods also (fish, meat, oil, milk) as well as in infant formula, where their levels, however, are usually lower than in breastmilk.[40]

Pesticides

DDT and other organo-chlorine pesticides, as well as their metabolites (e.g. hexachlorobenzene), are the chemical residues that were first found in breastmilk, where they accumulate due to their affinity with fats and to their long half-lives[41] (because they are difficult to metabolise and eliminate). Although they have been banned globally under the Stockholm Convention on POPs, they are still found in humans and in other mammals;[42] their levels, however, are decreasing. Many pesticides act as EDCs. In addition, they may cause headaches, irritability, dizziness, nausea, vomiting, tremors, excitation, convulsions, loss of consciousness, respiratory and central nervous system depression, and finally death. Organo-chlorine pesticides can occasionally be found in infant formula (including soy-based formula) and in baby foods, though usually at lower concentrations than in breastmilk.

Bisphenol A (BPA)

BPA has been used since the 1960s to make hard polycarbonate plastic bottles and cups, and to line metal and plastic food and beverage cans, including those containing liquid infant formula and soft drinks. As the compound leaches out easily, it has often been found in infant formula, derived partly from the polycarbonate plastic bottles, and partly from the linings of the can.[43] This continued until very recently, when major manufacturers of baby bottles, teats and formula started making their products without any BPA, even before legislation banned the compound in some countries. In many other countries, legislation has been late to be drafted; although food safety authorities worldwide have discussed BPA for years, they have been unable to reach a conclusion concerning its danger. The baby food industry has decided to avoid BPA because of consumer pressure and for fear of a fall in their sales, rather than because of a ban imposed by legislation. Because of its omnipresence, BPA easily enters the food chain and can be found in urine, blood, including the blood of pregnant women, the umbilical cord and breastmilk; foetuses and infants can therefore be exposed to BPA even if they are not fed polluted formula with a polluted bottle.[44] BPA is an EDC that mimics estrogens.[45] A 2008 report by the U.S. National Toxicology Program expressed concern for effects on the brain, behaviour, and the prostate gland in foetuses, infants, and children at current human exposures to BPA (via placenta, breastmilk, bottle feeding and feeding with polluted foods and beverages).

Phthalates

Commonly used to soften plastic items and make them more flexible, phthalates can be found in baby bottles, in other tools and toys for babies (such as pacifiers and teats), in materials used for health and personal care, and in medical equipment such as naso-gastric feeding tubes. As they are not chemically bound to the plastic, they are relatively easily released by evaporation and abrasion, and thus have the potential to enter the food chain and even to pollute breastmilk.[46] Phthalates have adverse effects on the liver, the kidneys and the reproductive system in particular, as they act as EDCs. Studies have shown that the

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[39] Zuurbier M, Leijs M, Schoeters G et al. Children's exposure to polybrominated diphenylethers. Acta Paediatr Suppl 2006;95:65-70

[40] Hoffman K, Adgent M, Davis Goldman B et al. Lactational exposure to polybrominated diphenyl ethers and its relation to social and emotional development among toddlers. Environ Health Perspect 2012; http://dx.doi.org/10.1289/ehp.1205100

[41] The time required for a quantity to fall to half its value.

[42] Eggesbo M, Stigum H, Longnecker MP et al. Levels of hexachlorobenzene (HCB) in breastmilk in relation to birthweight in a Norwegian cohort. Environ Res 2009;109:559-66

[43] Bucher J, Shelby M, National Institute of Environmental Health Sciences. Since you asked – Bisphenol A (BPA): Questions and Answers about Bisphenol A: http://www.niehs.nih.gov/health/topics/agents/sya-bpa/index.cfm

[44] LaKind JS, Naiman DQ. Daily intake of bisphenol A and potential sources of exposure: 2005-2006 National Health and Nutrition Examination Survey. J Expo Sci Environ Epidemiol 2011;21:272-9

[45] Braun JM, Kalkbrenner AE, Calafat AM et al. Impact of early-life bisphenol A exposure on behavior and executive function in children. Pediatrics 2011;128;873-82

[46] Fromme H, Gruber L, Seckin E et al, for the HBMnet. Phthalates and their metabolites in breastmilk: results from the Bavarian Monitoring of Breast Milk (BAMBI). Environment International 2011;37:715-22

intake of phthalate in formula-fed infants is of the same magnitude or up to four times higher than in exclusively breastfed infants. Also, the intake via breastmilk is generally low and unlikely to pose any significant health risk, at least in the short term. Nevertheless, other sources of pollution in infancy have to be considered and should be avoided. Many countries are considering drafting legislation to phase out and eventually ban phthalates from the market.

Benzo(a)pyrene and PAHs

Like benzene, toluene, naphthalene and many other compounds, benzo(a)pyrene belongs to the large family of so-called polycyclic aromatic hydrocarbons (PAHs). Its metabolites are mutagenic and highly carcinogenic, and it is listed as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC) of the WHO. The compound is one of the benzopyrenes, formed by a benzene ring fused to pyrene, and is the result of incomplete combustion at temperatures between 300 °C (572 °F) and 600 °C (1,112 °F). PAHs are the by-product of incomplete combustion or burning of organic items such as cigarettes, gasoline, wood, food, waste. They are thus found in cigarette smoke, grilled and broiled foods, exhaust gases, fumes during wood burning and waste incineration, and as by-products of many industrial processes (coke ovens, metal processing plants). PAHs are mostly found in air, but can be also be found in some food and water sources. As a consequence, they are mostly absorbed through air, but also via skin contact and food. Many PAHs are associated with damage to the bone marrow, changes in blood cells, alterations to sperm, abnormal physical development (reduced foetal growth, altered foetal blood formation, delayed ossification), alterations of the immune system and cancer (leukaemia). Infants can be exposed in utero through the placenta, and after birth through breastmilk, formula, and industrial baby foods. The amount of PAHs found in infant formula and baby food, almost always below the level considered dangerous by health authorities, is similar or higher - sometimes 2-3 times higher - than the amount found in breastmilk, which is therefore safer.[47] Benzene is also found in gasoline vapours and exhaust gases where gasoline is not regulated to contain low levels. It is a notorious cause of bone marrow failure: epidemiologic, clinical, and laboratory data link benzene to aplastic anaemia, acute and chronic leukaemia, bone marrow abnormalities, and myelo-dysplastic syndrome.

Metals

Mercury, lead, arsenic and cadmium are carcinogenic, pro-carcinogenic[48] and toxic for the brain, with effects on human cognitive development and intelligence. Severe *mercury* intoxication can result in congenital and/or postnatal cerebral palsy, as in the famous Minamata disaster, in Japan, in the late 1950s. The main source of mercury in the maternal diet is fish and sea mammals from polluted waters. Exposure to *lead* can be related to occupation (paint, explosives, batteries, metal melting, mining), to construction (renovation generating paint dust, hobbies like painting lead figurines or soldering electronics), to water (old lead pipes, pollution by mines or industry) and to tradition (folk remedies and cosmetics containing lead); until recently, tooth fillings were also a source of lead. Excess *arsenic* can be ingested when high levels are found in ground water, either naturally or due to arsenic-based pesticides and fertilisers; rice grown in polluted water may be an important source.[49] The most common source of *cadmium* is cigarette smoke; less important sources are occupational contacts (batteries, plastics, pigments, metal coatings) and diet (fish, animals and plants grown in cadmium polluted waters and soils). Cadmium is toxic for the kidney. Mercury, lead, arsenic, and cadmium, if present in the mother's blood, cross the placenta and may affect the development of the foetal brain during late gestation and in early infancy.[50] The level of these metals is highest at birth. The level of mercury in cord blood can be 1.5 higher than the level in maternal blood, while the levels of lead, arsenic, and cadmium are usually lower than those of the mother. All the birth levels tend to decrease after birth

[47] Kishikawa N, Wada M, Kuroda N et al. Determination of polycyclic aromatic hydrocarbons in milk samples by high-performance liquid chromatography with fluorescence detection. Journal of Chromatography B 2003;789:257-64

[48] A chemical substance is pro-carcinogenic when it becomes carcinogenic only after it is altered by some metabolic process.

[49] Fangstrom B, Moore S, Nermell B et al. Breastfeeding protects against arsenic exposure in Bangladeshi infants. Environ Health Perspect 2008;116: 963-9

[50] Dorea JG, Donangelo CM. Early (in uterus and infant) exposure to mercury and lead. Clinical Nutrition 2006;25:369-76

because metals are secreted in small quantities in breastmilk.[51] In exclusively breastfed babies, the level of mercury, for example, falls by approximately 60% at about 3 months of age, as compared to the level at birth. These metals, especially mercury and lead, are frequently found in infant formula, often at higher levels than in breastmilk - and without the protection provided by the latter. Their levels, via formula feeding, can be even higher if the powder is mixed with water polluted by metals. Reports of formula polluted by metals have been published in Germany, Australia, Canada, Sweden and, more recently, in China. Cow's milk containing heavy metals has been reported from countries worldwide, from Italy to Nigeria. Thus, to interrupt or suppress breastfeeding and replace it with a cow's milk-based formula should not be considered a serious option to counter pollution.

Melamine

Melamine is a synthetic product added to fertilizers to improve the growth of crops; it is also an ingredient of different plastics and as such it is found in many industrial goods. In 2007, a Chinese formula company deliberately added melamine to the diluted raw milk used to make powdered infant formula in order to boost its apparent protein content. As melamine is not degraded in humans and the main route of excretion is through the kidneys, infants fed on tainted formula suffered from acute renal failure, leading to death or to chronic disease, and from kidney stones.[52] The Chinese health authorities initially reported 432 cases of intoxication with one death; this was an underestimation that was later corrected to at least 6 deaths and about 300,000 cases. It was then disclosed that other formula manufacturers also had added melamine to their products and that these were consumed not only in China but exported to other countries in Asia and Africa. The rapidly falling rates of breastfeeding in China have resulted in a rush to produce and sell more and more infant formula, even when the raw material is scarce - much of the raw milk used by Chinese formula manufacturers comes from New Zealand. These lowering rates can in part be explained by two facts: first, women in China are recruited in huge and growing numbers to work in industries where, in the absence of adequate maternity protection legislation, their work conditions hinder breastfeeding. And second, and in parallel to this, there are few legislative measures in China that act as obstacles to counter the aggressive marketing of breastmilk substitutes by local and foreign companies.[53]

Mycotoxins

Mycotoxins are toxic metabolic products of moulds and are found in foods and feeds - cereals in particular - contaminated by moulds. The most studied group of mycotoxins are the aflatoxins, well-known as carcinogens. Aflatoxins can be found in breastmilk in populations that consume large quantities of contaminated cereals, especially in low income tropical countries where moulds grow fast and foods are rarely tested. In high income countries, mycotoxins are not frequently encountered in food or in breastmilk; however in these countries they can be found in industrial ready-to-eat baby foods (formula, meat-based infant foods) derived from animals that have been fed contaminated cereals.[54] It is very likely that in the future, strict legislation and control will progressively reduce this risk in high income countries, while in emerging economies, such as China, loose control and weak (or no) legislation will allow the risk to increase.

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[51] Sakamoto M, Man Chan H, Domingo JL et al. Changes in body burden of mercury, lead, arsenic, cadmium and selenium in infants during early lactation in comparison with placental transfer. Ecotoxicol Environ Saf 2012;84:179-84

[52] Guan N, Fan Q, Ding J et al. Melamine-contaminated powdered formula and urolithiasis in young children. N Engl J Med 2009;360:1067-74

[53] Gossner CME, Schlundt J, Embarek PB et al. The melamine incident: implications for international food and feed safety. Environ Health Perspect 2009;117:1803-8

[54] Meucci V, Soldani G, Razzuoli E et al. Mycoestrogen pollution of Italian infant food. J Pediatr 2011;159:278-83

Abstracts

Geraghty SR, Khoury JC, Morrow AL et al. Reporting individual test results of environmental chemicals in breastmilk: potential for premature weaning. Breastfeed Med 2008; 3:207-13

Although it is imperative to conduct studies on the links between detection frequency and effects of exposure to environmental chemicals in human milk, the potential impact of reporting individual test results to lactating women is poorly understood. The purpose of this study was to determine whether mothers wanted to know if there were chemicals in their breastmilk and if knowing the results would alter their breastfeeding practices. A total of 381 mothers participating in a longitudinal birth cohort in Cincinnati, Ohio, USA, were asked whether they wanted to receive individual test results for environmental chemicals in their milk and whether they would alter their breastfeeding patterns if they were told that their milk contained "low" or "high" levels of phthalates. Among the women who breastfed, 68% wanted to know if there were chemicals in their breastmilk. Amongst them, 78% and 93% reported that they would discontinue breastfeeding sooner than intended or pump and discard their milk if they were told they had, respectively, "low" or "high" levels of phthalates in their milk. African American women were significantly more likely than Caucasian women to report that they would immediately wean if told they had phthalates in their milk. As concern about environmental chemicals in breastmilk may lead to early termination of breastfeeding, researchers should recognize the potential implications of identifying and reporting environmental chemicals in breastmilk.

LaKind JS, Berlin CM, Sjödin A et al. Do human milk concentrations of persistent organic chemicals really decline during lactation? Chemical concentrations during lactation and milk/serum partitioning. Environ Health Perspect 2009;117:1625-31

Conventional wisdom regarding exposure to persistent organic chemicals via breastfeeding assumes that concentrations decline over the course of lactation. An important implication of this line of thought is that assessment of early childhood exposure should incorporate decreasing breastmilk concentrations over time. This study examined the rates of elimination of several groups of persistent organic chemicals in milk and blood samples of 10 women seeking prenatal care or with children receiving paediatric care in Hershey, Pennsylvania, USA. Participants provided serum and milk samples at 1, 2, and 3 months postpartum and at the cessation of lactation. Contrary to earlier research, the study found that concentrations of polybrominated diphenyl ethers (PBDE), polychlorinated biphenyls (PCB), dioxins and furans, and organochlorine pesticides in serum and milk do not decrease consistently during lactation and can indeed increase for some women. Thus, the concept of pumping and discarding early milk as a means of reducing very young infant exposure is not supported.

Fromme H, Gruber L, Seckin E et al. Phthalates and their metabolites in breast milk: results from the Bavarian Monitoring of Breast Milk (BAMBI). Environment International 2011;37:715-22

This study aimed to characterize the exposure of infants to phthalates in Germany. Overall, 15 different phthalates were analyzed in 78 breastmilk samples. The median concentrations varied from 0.8 to 3.9 ng/g for three phthalates, corresponding to median values in breastmilk from 2.1 to 11.8 μg/l; other phthalates were found in only some or none of the samples at levels above the limit allowed by the method used. Secondary metabolites were not detected in any samples. In four samples of infant formula, mean values ranging from 3.6 to 19.7 ng/g were observed. The estimated "average" and "high" daily intake for an exclusively breastfed infant was 0.1 to 6.4 μg/kg body weight for different phthalates, corresponding to only about 2% to 7%, respectively, of the recommended tolerable daily intake. Thus, it is not likely that an infant's exposure to phthalates from breastmilk poses any significant health risk. Nevertheless, other sources of phthalates in this vulnerable phase have to be considered. Moreover, it should be noted that for infants nourished with formula, phthalate intake is of the same magnitude or slightly higher than for exclusively breastfed infants.

Gascon M, Verner MA, Guxens M et al. Evaluating the neurotoxic effects of lactational

exposure to persistent organic pollutants (POPs) in Spanish children. NeuroToxicology 2013;34:9-15

This study was conducted to assess whether exposure to polychlorinated biphenyl-153 (PCB-153), dichlorodiphenyldichloroethylene (DDE) or hexachlorobenzene (HCB) through breastmilk, as opposed to the effects of prenatal exposure, is associated with mental and psychomotor impairment. A total of 1,175 children aged approximately 14 months were tested using the scores of the Bayley Scales of Infant Development. Exposure to PCB-153, DDE and HCB increased during the first months of life, yet no association was found between different periods of postnatal exposure and mental or psychomotor scores. Increasing prenatal PCB-153 concentrations were associated with lower mental and psychomotor scores, although significance was only reached for psychomotor development. The association between exposure and effects observed during prenatal life weakened gradually across periods of postnatal life. These results suggest that, although breastfeeding increases the level of persistent organic pollutants (POPs) in children during postnatal life, deleterious effects of PCB-153 on neuropsychological development are mainly attributable to prenatal exposure.

Sakamoto M, Chan HM, Domingo JL et al. Changes in body burden of mercury, lead, arsenic, cadmium and selenium in infants during early lactation in comparison with placental transfer. Ecotoxicology and Environmental Safety 2012;84:179-84

The objective of this study was to investigate the changes in body burden of mercury, lead, arsenic, cadmium and selenium in infants during a 3-month breastfeeding period, compared with placental transfer, in 16 mothers and their offspring in Fukuoka, Japan. Concentrations were measured in maternal and umbilical cord blood at delivery, and in infant blood at 3 months. The mercury level in cord was approximately 1.5 times higher than that in mothers, while in infants it declined by approximately 60% after 3 months of breastfeeding. The selenium level in cord blood was similar to the maternal level, but declined by approximately 75% in infants after 3 months of breastfeeding. Lead and arsenic concentrations in cord blood were about 60% of the maternal levels, and remained constant until 3 months. The cadmium level in cord blood was about 20% of that in maternal blood and remained almost constant until the end of the 3-month period. Although pregnant women should seek to avoid exposure, exposure through breastfeeding does not seem to pose any great concern for their child.

Meucci V, Soldani G, Razzuoli E et al. Mycoestrogen pollution of Italian infant food. J Pediatr 2011;159:278-83

To determine the concentrations of zearalenone, a nonsteroidal mycotoxin, and its metabolites in leading brands of infant formula and meat-based infant foods commonly marketed in Italy, 185 cow's milk-based infant formulas and 44 samples of meat-based infant foods were analyzed. Zearalenone was detected in 17 (9%) formula samples; its metabolites α-zearalenol and β-zearalenol were detected in 49 (26%) and 53 (28%) formula samples, respectively. Although α-zearalenol was detected in 12 (27%) meat samples, only one was contaminated by α-zearalanol, while zearalenone, β-zearalenol and β-zearalanol were not. This study shows the presence of mycoestrogens in infant milk-based and meat-based food, and this is likely to have great implications for subsequent generations, suggesting the need to perform occurrence surveys in these types of food. Mycotoxins in infant food probably derive from mycotoxins present in animal feeds.

Nachman RM, Fox SD, Golden WC et al. Urinary free bisphenol A and bisphenol A-glucuronide concentrations in newborns. J Pediatr 2013;162:870-2

The authors of this study examined the levels of urinary bisphenol A (BPA) in a sample of twelve healthy newborns, median age 17 days, recruited at Johns Hopkins Hospital, Baltimore, Maryland, USA, using a highly sensitive method. Urinary BPA was found in all samples. Questionnaire data revealed that ten of the twelve newborns had had some formula intake served in polycarbonate plastic bottles; five consumed formula made from powder and four drank liquid or "ready-to-feed" formula, which requires no addition of water.

Lachenmeier DW, Maser E, Kuballa T et al. Detailed exposure assessment of dietary furan for infants consuming commercially jarred complementary food based on data from the DONALD study. Maternal and Child Nutrition 2012;8:390-403

This paper provides an assessment of the exposure to furan - a possible human carcinogen - in babies consuming jars of complementary foods. The survey of commercial ready-to-eat complementary foods included 282 products sampled and analysed between 2004 and 2010. The products included beverages (fruit juices, teas, tea-juice mixtures and others), fruits and vegetables (including vegetarian menus without meat), menus (combinations of vegetables, meat and potatoes/ pasta/cereals), meat (exclusively or predominantly based on meat), porridge (combinations of cereals and milk), and infant formulas. The average furan content in meals and menus was between 20 and 30 µg/kg, corresponding to an estimated exposure for consumers of commercially jarred foods between 182 and 688 ng/kg per day - with a worst-case scenario ranging between 351 and 1066 ng/kg/day. This level of exposure is associated with an increased risk of liver cancer in rats. Measures to avoid furan in complementary foods should be of high priority for risk management.

Schier JG, Wolkin AF, Valentin-Blasini L et al. Perchlorate exposure from infant formula and comparisons with the perchlorate reference dose. Journal of Exposure Science and Environmental Epidemiology 2010;20:281-7

Perchlorate adversely affects the function of the thyroid gland by inducing a functional state of iodide deficiency. This study assessed perchlorate concentrations in commercially available powdered infant formulas (PIFs) to estimate exposure in infants. Perchlorate levels were quantified in three samples of reconstituted PIF (using perchlorate-free water) from commercial brands of PIF in each of the following categories: bovine milk-based with lactose, soy-based, bovine milk-based but lactose-free, and elemental (typically consisting of synthetic amino acids). The results were as follows: bovine milk-based with lactose: 1.72 mg/l, range: 0.68–5.05; soy-based: 0.21 mg/l, range: 0.10–0.44; lactose-free: 0.27 mg/l, range: 0.03–0.93; elemental: 0.18 mg/l, range: 0.08–0.4. Bovine milk-based PIFs with lactose had a significantly higher concentration of perchlorate compared with all other PIFs. Perchlorate was a contaminant found in all of the commercially available PIFs tested. The maximum dose of perchlorate allowed may be exceeded when certain bovine milk-based PIFs are ingested and/ or when PIFs are reconstituted with perchlorate contaminated water.

Royal College of Obstetricians and Gynaecologists. Chemical exposures during pregnancy: dealing with potential, but unproven, risks to child health. RCOG Scientific Impact Paper 37, 2013 http://www.rcog.org.uk/files/rcog-corp/5.6.13ChemicalExposures.pdf

This recent publication by the RCOG in UK is meant to inform pregnant and breastfeeding women about the sources and routes of chemical exposure so that they will be able to take action in order to minimize the risks to their child. The authors of the document reviewed the literature on this subject, in particular on the effects of EDCs, explaining that the evidence is inconclusive, mainly because the methods for assessing the full risk of exposure are not yet developed. They suggest, however, a "safety first" approach for pregnant women, that is to assume that there is a risk even if it may be minimal. The document recommends to use fresh food whenever possible, and to reduce the consumption of food in cans and plastic containers; to minimize the use of personal care products and household chemicals; to avoid paint fumes and use of all pesticides; and to take over-the-counter medicines only when necessary. The authors do not deal with recommendations regarding infant and young child feeding.

Díaz-Gómez NM, Ares S, Hernández-Aguilar MT et al. for the Breastfeeding Committee of the Spanish Association of Paediatrics. Contaminantes químicos y lactancia materna: tomando posiciones. An Pediatr (Barc) 2013 http://dx.doi.org/10.1016/j.anpedi.2013.04.004

Chemical pollution affects all ecosystems of our planet. Human milk has been used as a biomarker of environmental pollution because, due to bioaccumulation processes in fat tissue, many chemical compounds reach measurable concentrations that can be readily tested in breastmilk. Quite frequently information about the presence of chemical residues in breastmilk appears in the media, leading to misunderstanding among parents and health professionals, and in some cases to stopping breastfeeding. In this position paper, the Breastfeeding Committee of the Spanish Association of Paediatrics stresses the importance of promoting breastfeeding as the healthiest option, because its benefits clearly outweigh any health risks associated with chemical residues in breastmilk. Breastmilk contains protective factors

that counteract the potential effects related to prenatal exposure to environmental pollutants. The article summarises the key recommendations to reduce the level of chemical residues in breastmilk. It also highlights the importance of government involvement in the development of programmes to eliminate or reduce chemical pollution of food and the environment. In this way, the negative effects on child health resulting from exposure to these toxic compounds through the placenta and breastmilk may be prevented.

Prepared by the Geneva Infant Feeding Association (GIFA), an affiliate of the International Baby Food Action Network (IBFAN)

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