Supplementary material



**Supplementary Figure 1**: Search methods are included for a) HIV through breastfeeding; b) HTLV-1 through breastfeeding; and c) *Cronobacter* and *Salmonella* through PIF. Databases used include Scopus and Web of Science (All databases).

Supplementary Table 1: Maternal viral infections where transmission of the virus through breastfeeding is not common.

|  |  |  |
| --- | --- | --- |
| **Virus** | **Breastfeeding recommendation** | **References** |
| Hepatitis B | Breastfeeding is not contraindicated when recommended prophylaxis is implemented | (1) |
| Hepatitis C | Breastfeeding not contraindicated unless nipples are cracked | (2) |
| Epstein-Barr virus | Breastfeeding not contraindicated | (3) |
| Herpes Simplex Virus I and II | Breastfeeding not contraindicated unless there is a lesion in the nipple | (4, 5) |
| Human Herpes virus 6 and 7 | Breastfeeding not contraindicated | (6, 7) |
| Human Papilloma Virus | Breastfeeding not contraindicated | (8) |
| Dengue | Breastfeeding not contraindicated but recommendation needs to be made on an individual basis | (9) |
| Ebola virus | Replacement formula and separation form mother is recommended except where infant already has Ebola and risk associated with replacement formula outweighs risk of breastfeeding  | (10) |
| Yellow fever (Vaccine strain viruses) | Vaccination should be avoided during breastfeeding where possible. Some experts recommend avoiding breastfeeding for 2 weeks after vaccination | (11) |
| Rubella (Vaccine strain viruses) | Breastfeeding not contraindicated | (12) |
| Parvovirus (Vaccine strain viruses) | Breastfeeding not contraindicated | (13) |
| Zika Virus | Breastfeeding not contraindicated | (14) |

**Supplementary Table 2:** Microbial disease assocaited with the process of donated or expressed breast milk.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Bacteria | Attributed source of contamination | Infant feeding (PDHM or EBM) | Associated with infant illness | Mortality | Reference |
| *Acinetobacter baumanaii* | Outer surface of breast pump in an NICU | EBM |  2 symptomatic, 5 aymptomatic  | 0 | (15) |
| *Bacillus cereus* | Possibly pooled PDHM (source not isolated) | PDHM | 1 symptomatic infant | 0 | (16) |
| Β-lactamase-producing *Escherichia coli* | EBM | EBM | 6 colonised infants in NICU | 0 | (17) |
| *Cronobacter sakazakii* | Unknown, contaminated brest milk pump, contaminated breast pump | gavage fed EBM mixed with commercial liquid human milk fortifier, EBM  | 3 symtomatic infants  | 0 | (18-20) |
| *Escherichia coli* | Unhygienic handling of pooled EBM (autoclaved at 109°C for 3-5 min at 6-7 pounds of pressure), EBM  | Pooled EBM, enteral feeding with EBM | 5 syptomatic infants, 10 colonised at an NICU | 0 | (21, 22) |
| Group B *Streptococcus* | EBM  | EBM | 4 symptomatic infants  | 0 | (23, 24) |
| *Klebsiella pneumoniae* | EBM, contaminated breast pump | EBM, enteral EBM, PDHM | 8 symtomatic infants | 0 | (22, 24, 25) |
| *Pseudomonas aeruginosa* | Contaminated breast pump | EBM | 1 symptomatic infant | 0 | (26) |
| *MRSA* | EBM (breast pump not tested), EBM from mother with mastitis | Enteral EBM, EBM through nasogastric tubing | 2 symptomatic infants, 4 asymptomatic infansts |  | (26, 27) |
| *Salmonella knottbus* | Improper handling of donated EBM (unpasteurised) in a NICU | Donated EBM | 3 symptomatic infants, 4 asymptomatic infants | 0 | (28) |
| *Salmonella typhimurium* | EBM from a mother with *S. typhimurium* infection, EBM from asymptomatic mother | EBM, breastfeeding/EBM | 9 symtomatic infants, 3 aymptomatic infants | 0 | (29, 30) |
| *Salmonella enterica* serotype Panama | EBM from asymptomatic mother  | EBM | 1 symtomatic infant | 0 | (31) |
| *Staphylococcus aureus* | EBM from asymptomatic mother | Breastfeeding and EBM | 1 symtomatic infant | 0 | (32) |
| *Serratia marcencens* | Inadequate sterilization of breast pumps | EBM | 30 asymptomatic | 0 | (33) |

EBM = Expressed breast milk, PDHM = Pasteurised donor human milk

Supplementary Table 3: Pathogens associated with PIF and infections attributed to pathogens in PIF.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Bacteria | Isolation source | Morbidity associated with PIF consumption N (ref) | Pathogen traced to PIF | Reference |
| *Acinetobacter baumii* | FUF | No | No | (34) |
| *Bacillus cereus* | PIF, FUF | No | No | (35-37) |
| *Cadacea davisae* | PIF (NICU) | No | No | (38) |
| *Cedecea lapagei* | PIF | No | No | (39) |
| *Citrobacter freundii* | PIF, FUF | No | No | (34, 38, 40-42) |
| *Citrobacter koseri* | PIF | No | No | (37, 40) |
| *Clostridium botulism* | Opened PIF | Yes | Yes | (43, 44) |
| *Clostridium difficile* | PIF | No | No | (45) |
| *Cronobacter sakazakii* | PIF | Yes | Yes | See *Cronobacter* table |
| *Enterobacter agglomerans* | PIF | Yes | No | (46) |
| *Enterobacter cancerogenus* | Enteral feeding tubes | No | No | (47) |
| *Enterobacter cloacae* | Processing plants, PIF, FUF, infant formula room (hospital) | Yes - 1 death (48) | Possible | (34, 41, 46, 48-50) |
| *Enterobacter hormaechei* | PIF | Yes – 7 (51), 2 (52) | Yes (suspected) | (42, 47, 51, 52) |
| *Escherichia coli* | PIF, enteral feeding tubes | No | No | (40, 41, 47, 53) |
| *Escherichia hermanii* | PIF | No | No | (37, 50) |
| *Escherichia vulneris* | PIF | No | No | (37, 40, 47) |
| *Klebsiella oxytoca* | Survives desiccation for over 2 years | No | No | (40) |
| *Klebsiella pneumoniae* | Processing plant, PIF, FUF and enteral feeding tubes | Yes (54) | No | (34, 38, 41, 46, 49, 50) |
| *Leclercia adecarboxylata* | Processing plant and PIF | No | No | (49) |
| *Legionella pneumophila* | Contaminated water used for PIF | Yes - 2 (55) | No | (55) |
| *Listeria monocytogenes* | PIF (NICU) | No | No | (35) |
| *Pantoea* spp. | PIF | No | No | (37, 40, 49, 50, 56) |
| *Pseudomonas aeruginosa* | PIF, feeding bottles and milk pasteurizers (NICU) | No | No | (57, 58) |
| *Salmonella* spp. | Processing plant, PIF | Yes | Yes | See *Salmonella* Table |
| *Serratia ficaria* | PIF, FUF | No | No | (34) |
| *Serratia marascens* | Enteral feeding tubes | No | No | (47) |
| Shiga toxin-producing *Escherichia coli* |  |  |  |  |
| *Shigella* spp. | Baby bottles | Yes | No | (59) |
| *Staphylococcus aureus* | PIF, feeding bottles, infant formula room (hospital) | No | No | (60, 61) |

FUF=Follow-up formula; NICU=neonatal intensive care unit

**Supplementary Table 4**: Recall list (2014-1019) compiled from IBFAN (International Baby Food Action Network) recall lists and papers from Scopus and Web of Science for the last 5 years. More extensive IBFAN recall lists which go back to 2000 can be found on the IBFAN website (62, 63).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year | Country | Reason for recall | Company | Reported symptomatic infants/ fatalities | Source |
| 2019 | International | *Salmonella enterica* contamination in rice-based PIF | Sodilac and Lactalis | 32/0 | (64)  |
| 2018 | Singapore | *Cronobacter sakazakii* was found in test samples | Mamil Gold (Dumex) | / | (64) |
| 2018 | France | Precautionary recall due to accidental dispatch of tins intended for industrial testing (suspected contamination with *Cronobacter sakazakii)* | Guigoz (Nestle) | / | (64) |
| 2018 | Chile | *Staphylococcus aureus* detected in batch (expanded alert to all batches of PreNan)  | PreNan (Nestle) |  | (64) |
| 2018 | Chile | Mould detected in one batch | PreNan (Nestle) | / | (64) |
| 2018 | Chile | Contamination of PIF with *Bacillus cereus* | Wyeth | 3/0 | (64) |
| 2018 | France | Contamination of *Cronobacter sakazakii* | Premilait 0-6 months (Premiobio) | / | (64) |
| 2018 | France | Salmonella infection attributed to PIF | Picot AR Modilac (Lactalis) | 7/0 | (65) |
| 2017 | France, some other countries in Europe | Salmonella outbreak | Lactalis | 41/0 | (66) |
| 2017 | Dominican Republic | Detection of *Cronobacter sakazakii* | Nutriben AC Digest | / | (64) |
| 2016 | Hong Kong | Detection *of Cronobacter sakazakii* before distribution | Holle Bio-Anfangsmilch | / | (64) |
| 2016 | USA | Non-compliance with microbiological testing | Sammy’s Milk Baby Food | / | (64) |
| 2016 | Canada | Imbalance of nutrients in products – FDA recall | Nestle | / | (64) |
| 2015 | Argentina | Samples contaminated with *Cronobacter sakazakii* | SanCor | / | (64) |
| 2014 | Canada | Tins of ready-to-feed Infant formula in stores were tampered with | Enfamil (Mead Johnson) | / | (64) |

**Supplementary References**

1. Wang T, Wang M, Duan G *et al.* (2015) Discrepancy in impact of maternal milk on vertical transmission between Hepatitis B virus and Human cytomegalovirus. *International Journal of Infectious Diseases* 37, e1-e5.

2. Workowski KA & Bolan GA (2015) Sexually transmitted diseases treatment guidelines, 2015. *MMWR Recommendations and reports: Morbidity and mortality weekly report Recommendations and reports* 64, 1.

3. Association AP (2019) Epstein-Barr Virus (EBV) And Infectious Mononucleosis. <https://americanpregnancy.org/pregnancy-complications/epstein-barr-virus-ebv-infectious-mononucleosis/>

4. Prevention CfDCa (2018) Herpes Simplex Virus (HSV). <https://www.cdc.gov/breastfeeding/breastfeeding-special-circumstances/maternal-or-infant-illnesses/herpes.html> (accessed 2.12.19

5. Allen UD, Robinson JL, Society CP *et al.* (2014) Prevention and management of neonatal herpes simplex virus infections. *Paediatrics & child health* 19, 201-206.

6. Kusuhara K, Takabayashi A, Ueda K *et al.* (1997) Breast milk is not a significant source for early Epstein-Barr virus or human herpesvirus 6 infection in infants: A seroepidemiologic study in 2 endemic areas of human T-cell lymphotropic virus type I in Japan. *Microbiology and Immunology* 41, 309-312.

7. Gantt S, Carlsson J, Shetty AK *et al.* (2008) Cytomegalovirus and Epstein-Barr virus in breast milk are associated with HIV-1 shedding but not with mastitis. *AIDS* 22, 1453-1460.

8. Yoshida K, Furumoto H, Abe A *et al.* (2011) The possibility of vertical transmission of human papillomavirus through maternal milk. *Journal of Obstetrics and Gynaecology* 31, 503-506.

9. Arragain L, Dupont-Rouzeyrol M, O'connor O *et al.* (2016) Vertical transmission of dengue virus in the peripartum period and viral kinetics in newborns and breast milk: new data. *Journal of the Pediatric Infectious Diseases Society* 6, 324-331.

10. Organization WH (2015) Nutritional care of children and adults with Ebola virus disease in treatment centres: World Health Organization Geneva.

11. Anstey EH, Shealy, K. R. (2020) *Family Travel, Chapter 7, Yellow Book.* USA: Oxford University Press.

12. Prevention CfDCa (2018) Vaccination Safety for Breastfeeding Mothers. <https://www.cdc.gov/breastfeeding/breastfeeding-special-circumstances/vaccinations-medications-drugs/vaccinations.html>

13. Smith-Norowitz TA, Drew H, Norowitz HM *et al.* (2008) Detection of IgE anti-parvovirus antibodies in human breast milk. *Annals of Clinical and Laboratory Science* 38, 168-173.

14. Davanzo R (2018) Controversies in Breastfeeding. *Front Pediatr* 6.

15. Engür D, Çetinkaya Çakmak B, Kaynak Türkmen M *et al.* (2014) A milk pump as a source for spreading Acinetobacter baumannii in a neonatal intensive care unit. *Breastfeeding Medicine* 9, 551-554.

16. Decousser J-W, Ramarao N, Duport C *et al.* (2013) Bacillus cereus and severe intestinal infections in preterm neonates: putative role of pooled breast milk. *American Journal of Infection Control* 41, 918-921.

17. Nakamura K, Kaneko M, Abe Y *et al.* (2016) Outbreak of extended-spectrum β-lactamase-producing Escherichia coli transmitted through breast milk sharing in a neonatal intensive care unit. *J Hosp Infect* 92, 42-46.

18. Ravisankar S, Syed SS, Garg P *et al.* (2014) Is Cronobacter sakazakii infection possible in an exclusively breastfed premature neonate in the neonatal intensive care unit. *Journal of Perinatology* 34, 408-409.

19. Bowen A, Wiesenfeld HC, Kloesz JL *et al.* (2017) Cronobacter sakazakii infection associated with feeding extrinsically contaminated expressed human milk to a premature infant — Pennsylvania, 2016. *Morbidity and Mortality Weekly Report* 66, 761-762.

20. McMullan R, Menon V, Beukers AG *et al.* (2018) Cronobacter sakazakii infection from expressed breast milk, Australia. *Emerging Infectious Diseases* 24, 393-394.

21. Stiver HG, Albritton WL, Clark J *et al.* (1977) Nosocomial colonization and infection due to E. coli 0125:K70, epidemiologically linked to expressed breast-milk feedings. *Canadian Journal of Public Health* 68, 479-482.

22. Widger J, O’Connell NH Stack T (2010) Breast milk causing neonatal sepsis and death. *Clinical Microbiology and Infection* 16, 1796-1798.

23. Olver WJ, Bond DW, Boswell TC *et al.* (2000) Neonatal group B streptococcal disease associated with infected breast milk. *Archives of Disease in Childhood: Fetal and Neonatal Edition* 83, F48-F49.

24. Godambe S, Shah PS Shah V (2005) Breast milk as a source of late onset neonatal sepsis. *Pediatric Infectious Disease Journal* 24, 381-382.

25. Donowitz LG, Marsik FJ, Fisher KA *et al.* (1981) Contaminated breast milk: A source of klebsiella bacteremia in a newborn intensive care unit. *Reviews of Infectious Diseases* 3, 716-720.

26. Smith SL & Serke L (2016) Case Report of Sepsis in Neonates Fed Expressed Mother's Milk. *Journal of Obstetric Gynecologic and Neonatal Nursing* 45, 699-705.

27. Behari P, Englund J, Alcasid G *et al.* (2004) Transmission of methicillin-resistant Staphylococcus aureus to preterm infants through breast milk. *Infection Control & Hospital Epidemiology* 25, 778-780.

28. Ryder RW, Crosby Ritchie A, McDonough B *et al.* (1977) Human Milk Contaminated With Salmonella kottbus: A Cause of Nosocomial Illness in Infants. *JAMA: The Journal of the American Medical Association* 238, 1533-1534.

29. Drhova A, Dobiasova V Stefkovicova M (1990) Mother's milk--unusual factor of infection transmission in a salmonellosis epidemic on a newborn ward. *Journal of Hygiene, Epidemiology, Microbiology, and Immunology* 34, 353-355.

30. Qutaishat SS, Stemper ME, Spencer SK *et al.* (2003) Transmission of Salmonella enterica serotype Typhimurium DT104 to infants through mother's breast milk. *Pediatrics* 111, 1442-1446.

31. Chen T-L, Thien P-F, Liaw S-C *et al.* (2005) First report of Salmonella enterica serotype Panama meningitis associated with consumption of contaminated breast milk by a neonate. *Journal of clinical microbiology* 43, 5400-5402.

32. Kayiran PG, Can F, Kayiran SM *et al.* (2014) Transmission of methicillin-sensitive Staphylococcus aureus to a preterm infant through breast milk. *Journal of Maternal-Fetal and Neonatal Medicine* 27, 527-529.

33. Gransden W, Webster M, French G *et al.* (1986) An outbreak of Serratia marcescens transmitted by contaminated breast pumps in a special care baby unit. *J Hosp Infect* 7, 149-154.

34. Chap J, Jackson P, Siqueira R *et al.* (2009) International survey of Cronobacter sakazakii and other Cronobacter spp. in follow up formulas and infant foods. *International Journal of Food Microbiology* 136, 185-188.

35. El-Gamal MS, El Dairouty RK, Okda AY *et al.* (2013) Incidence and interrelation of Cronobacter sakazakii and other foodborne bacteria in some milk products and infant formula milks in Cairo and Giza area. *World Applied Sciences Journal* 26, 1129-1141.

36. Haughton P, Garvey M Rowan NJ (2010) Emergence of Bacillus cereus as A dominant organism in Irish retailed Powdered Infant Formulae (PIF) when reconstituted and stored under abuse conditions. *Journal of Food Safety* 30, 814-831.

37. Hwang JY, Lee JY Park JH (2008) Microbiological quality and potential pathogen monitoring for powdered infant formulas from the local market. *Korean Journal for Food Science of Animal Resources* 28, 555-561.

38. Carneiro LAM, Silva APS, Merquior VLC *et al.* (2003) Antimicrobial resistance in Gram-negative bacilli isolated from infant formulas. *FEMS Microbiology Letters* 228, 175-179.

39. Heperkan D, Dalkilic-Kaya G Juneja VK (2017) Cronobacter sakazakii in baby foods and baby food ingredients of dairy origin and microbiological profile of positive samples. *LWT - Food Science and Technology* 75, 402-407.

40. Barron JC & Forsythe SJ (2007) Dry stress and survival time of Enterobacter sakazakii and other Enterobacteriaceae in dehydrated powdered infant formula. *Journal of Food Protection* 70, 2111-2117.

41. Güner A, Doǧruer Y, Cebirbay MA *et al.* (2011) An investigation on the prevalence of Cronobacter sakazakii in powdered infant formula consumed in Turkey. *Journal of Food, Agriculture and Environment* 9, 82-84.

42. Giammanco GM, Aleo A, Guida I *et al.* (2011) Molecular epidemiological survey of Citrobacter freundii misidentified as Cronobacter spp.(Enterobacter sakazakii) and Enterobacter hormaechei isolated from powdered infant milk formula. *Foodborne Pathog Dis* 8, 517-525.

43. Brett M, McLauchlin J, Harris A *et al.* (2005) A case of infant botulism with a possible link to infant formula milk powder: evidence for the presence of more than one strain of Clostridium botulinum in clinical specimens and food. *Journal of Medical Microbiology* 54, 769-776.

44. Barash JR, Hsia JK Arnon SS (2010) Presence of soil-dwelling clostridia in commercial powdered infant formulas. *The Journal of Pediatrics* 156, 402-408.

45. Saad NM, Amin WF Shaker EM (2013) Detection of toxigenic Clostridium difficile in powdered infant and follow-up formulae in Egypt. *Veterinary World* 6, 862.

46. Muytjens HL, Roelofs-Willemse H Jaspar GHJ (1988) Quality of powdered substitutes for breast milk with regard to members of the family Enterobacteriaceae. *Journal of Clinical Microbiology* 26, 743-746.

47. Hurrell E, Kucerova E, Loughlin M *et al.* (2009) Neonatal enteral feeding tubes as loci for colonisation by members of the Enterobacteriaceae. *BMC Infectious Diseases* 9, 146.

48. Caubilla-Barron J, Hurrell E, Townsend S *et al.* (2007) Genotypic and phenotypic analysis of Enterobacter sakazakii strains from an outbreak resulting in fatalities in a neonatal intensive care unit in France. *Journal of Clinical Microbiology* 45, 3979-3985.

49. Popp A, Iversen C, Fricker-Feer C *et al.* (2009) Identification of Enterobacteriaceae isolates from raw ingredients, environmental samples and products of an infant formula processing plant. *Archiv fur Lebensmittelhygiene* 60, 92-97.

50. Estuningsih S, Kress C, Hassan AA *et al.* (2006) Enterobacteriaceae in dehydrated powdered infant formula manufactured in Indonesia and Malaysia. *Journal of Food Protection* 69, 3013-3017.

51. Townsend SM, Hurrell E, Caubilla-Barron J *et al.* (2008) Characterization of an extended-spectrum beta-lactamase Enterobacter hormaechei nosocomial outbreak, and other Enterobacter hormaechei misidentified as Cronobacter (Enterobacter) sakazakii. *Microbiology-(UK)* 154, 3659-3667.

52. Jackson EE, Flores JP, Fernández-Escartín E *et al.* (2015) Reevaluation of a suspected Cronobacter sakazakii outbreak in Mexico. *Journal of Food Protection* 78, 1191-1196.

53. Kassier SM & Veldman FJ (2013) Cry, the beloved bottle: Infant-feeding knowledge and the practices of mothers and caregivers in an urban township outside Bloemfontein, Free State province. *South African Journal of Clinical Nutrition* 26, 17-22.

54. Sun F, Wu D, Qiu Z *et al.* (2010) Development of real-time PCR systems based on SYBR Green for the specific detection and quantification of Klebsiella pneumoniae in infant formula. *Food Control* 21, 487-491.

55. Wei SH, Chou P, Tseng LR *et al.* (2014) Nosocomial Neonatal Legionellosis Associated with Water In Infant Formula, Taiwan. *Emerging Infectious Diseases* 20, 1921-1924.

56. Mardaneh J & Soltan Dallal MM (2013) Isolation, identification and antimicrobial susceptibility of Pantoea (Enterobacter) agglomerans isolated from consumed powdered infant formula milk (PIF) in NICU ward: First report from Iran. *Iranian Journal of Microbiology* 5, 263-267.

57. Edwards LD, Tan-Gatue LG, Levin S *et al.* (1974) The Problem of Bacteriologically Contaminated Infant Formulas in a Newborn Nursery. *Clinical Pediatrics* 13, 63-65.

58. Sánchez-Carrillo C, Padilla B, Marín M *et al.* (2009) Contaminated feeding bottles: The source of an outbreak of Pseudomonas aeruginosa infections in a neonatal intensive care unit. *American Journal of Infection Control* 37, 150-154.

59. de Moraes MS, AraÚjo BC, de Oliveira Costa LE *et al.* (2015) Shigella in baby bottles of a brazilian newborn nursery. *Journal of Infection in Developing Countries* 9, 679-681.

60. Zhang Y, Qiao MY Wang X (2016) Prevalence of staphylococcus aureus contamination in infant foods and the detection of antibiotic resistance genes and new enterotoxin genes. *Modern Food Science and Technology* 32, 280-285.

61. Wang X, Meng J, Zhang J *et al.* (2012) Characterization of Staphylococcus aureus isolated from powdered infant formula milk and infant rice cereal in China. *International Journal of Food Microbiology* 153, 142-147.

62. IBFAN (2007) Product Recall List (from 2000 to 2007).

63. IBFAN (2010) Product Recall List 2007-2010.

64. IBFAN-ICDC (2019) Product Recall List (2014-2019).

65. European Centre for Disease Prevention and Control & European Food Safety Authority (2019) Multi‐country outbreak of Salmonella Poona infections linked to consumption of infant formula. *EFSA Supporting Publication* 16, EN-1594.

66. European Food Safety Authority, Prevention ECfD Control (2018) Multi-country outbreak of Salmonella Agona infections linked to infant formula. *EFSA Supporting Publications* 15, EN-1365.