Interactions of:
Malnutrition,
Water Sanitation and Hygiene,
Infections

Version 2005, revised 2007, produced (CD format) 2007

INDEX

EXECUTIVE SUMMARY

Malnutrition is a global problem in which there are factors other than a lack of food – for example infections. Drinking water, and more generally "domestic" water (including water necessary for hygiene and sanitation practices), is often a source of disease because of its poor quality (it can contain bacteria, viruses, parasites as well as chemical agents) and its scarcity. Inadequate sanitary conditions lead to the death of 1.5 million children each year worldwide, with 88% of these deaths due to diarrhoea. Diarrhoea is often linked to insufficient quantities of water to enable a minimum of hygiene (e.g. washing hands), a situation frequently exacerbated by the absence of toilet facilities, which in turn leads to the contamination of drinking water and water ressource in general.

For all these reasons, it is natural that Action contre la Faim – which positions itself as both treating and preventing malnutrition (especially through the water-sanitation-hygiene component) – examines exactly how these factors interact and draw conclusions for its work.

Diarrhoea

In developing countries, bacterial or viral gastroenteritis represents one of the main causes of morbidity / mortality among children. The annual rate of diarrhoeic disease in these countries for children under 5 is estimated at 3.2 events per child.

It was traditionally thought that the causes of diarrhoea would be limited by improving hygiene and sanitation. But this approach is insufficient in the case of viruses, which are more resistant.

In endemic zones, parasitic colonisation of the intestine is the norm. Since malnutrition is one of the major causes of immune deficiency, parasitic diarrhoea is frequent and acute among malnourished children, whereas well-fed children remain healthy carriers.

Interaction of Diarrhoea and Malnutrition

Diarrhoea can be considered as a cause and consequence of malnutrition. Diarrhoea prevents children from achieving normal growth, while malnutrition increases the frequency and the duration of diarrhoeic events, thereby creating a vicious circle.

Infection has a negative effect on the nutritional state for a number of reasons: by reducing appetite and intestinal absorption, and by increasing catabolism and the stocking of micro-nutrients needed for tissue formation and growth. Mathematical models calculate that a quarter to a third of cases of retarded growth is due to intestinal infections.

Since the 1980s, malnutrition – even mild – has been recognised as sufficient for weakening immune defences. The role of micro-nutrients in allowing adequate immune responses to attacks is now accepted, and the pathological effects of the most common types of deficiency are also recognised.

Protective role of breastfeeding with regards to infection and malnutrition

In 2000 a team of WHO experts studying the impact of breastfeeding on the prevention of infant mortality clearly demonstrated that breastfeeding protects babies against the risks of diarrhoeic infections, which led to a recommendation for a 6 month period of breastfeeding

exclusively. However, the transmission of the HIV virus via the mother's milk raises a problem here.

Water/Sanitation/Hygiene and the vicious circle of Infection/Malnutrition

 Hundreds of millions of people, mostly children, die each year from diseases directly linked to a lack of basic hygiene. Action relating to hygiene, sanitation and water supply has shown that it is possible to reduce the frequency, severity and economic impact of disease.

At the Kyoto summit in 2003, it was recognised that efforts should no longer be focused solely on the quality of water but also on hygiene and sanitation (removal of waste water), with governments to develop strategies aimed at reducing by 50% the number of people without toilets by 2015, and to concentrate on basic hygiene promotion, especially hand washing.

Access to water has been the subject of numerous reports that have stressed the limited capacity of 'liberal' systems to resolve these problems. Non-existent or inadequate access to water has severe consequences on children's growth and weight gain. And the effects of a lack of water during childhood continue for the rest of a person's life.

Maintaining water quality is particularly important in preventing epidemics, including in industrialised countries.

Impact on diarrhoea from improving water supply

 Improving water supply and sanitation has a very significant effect on the mortality and morbidity of different infections. For diarrhoea, the reduction in morbidity (incidence and prevalence) is of 25% when access to water is improved; 22% when disposal of human waste is improved; and 16% when water quality is improved. But these effects are not entirely cumulative, since if water access and quality are both improved, the reduction is 37%, rather than the 41% expected in theory.

Among their conclusions, these studies stressed the necessity of improving the quality (protection, treatment) and quantity of water available to homes in order to remove the need to store water in receptacles that are a source of contamination. These improvements reduce the incidence of diarrhoea and support children's growth.

The role of hygiene

Most endemic diarrhoeas are not linked to the transmission of pathogens through water but are passed between people because of a lack of hygiene. The impact of hand washing with soap (which of course requires water and soap) on diarrhoeic infection in high-risk populations has been widely studied. Although none of these studies is beyond methodological criticism, they all conclude that there is a positive effect and a reduction of around 47% in the risk of contracting a diarrhoeic infection. In terms of the reduction of mortality, the estimate is for around 17%, or about 1 million children per year.

INTRODUCTION

Malnutrition is a major issue in the world. Nevertheless there exist other factors than food shortage that play an important part, among others infections especially in chronic malnutrition (involving stunting).

Infection can be defined as the detrimental colonization of a host organism, of a foreign species (such as bacteria, viruses, fungi, and parasites) which is generally pathogen and able to multiply. The latin origin of the word "inficere" meaning poisoning evidences the real negative impact of the process. There are several types of infections: they can be local infections, infections specific to an organ and disseminated infections. Indeed gastro-intestinal infections are the most common, especially with children.

Besides the malnutrition charts are often related to diarrheas ; the factors causing stunting (evidencing chronic malnutrition), diarrhea being both the cause and the consequence of the phenomenon (Guerrant, 1992). This link can be explained by iterative diarrheic episodes which reduce children's height and weight gains, no matter what's the cause. In case of repeated episodes, it is not possible to observe the growth "catching-up" that usually takes place after such infection phases (or acute malnutrition periods). Pathological phases are often due to feedwater –and more generally the so-called "domestic water"- because of bacteria, viruses, parasites, but also chemicals it conveys. In the world, the main cause of the death of 1.5 million children is precarious sanitation environment. It is assumed that 88% of these deaths are due to diarrhea (Black (2),2003) (Parry-Jones, 2003). The causes of these diarrheas are due to the available quantities of water (often insufficient to secure minimum sanitation) which can be associated with the fact that no latrines exist (which leads to contaminated drinking water) (Murray, 2002 and Ezzati, 2002). Besides these material factors, we must not underestimate the negative impact of the daily water "duty" that is taken care of by mothers (Levine, 2001) and which keep them away from the home, sometimes for quite a distance and prevent them from giving close attention to their very young children in terms of care and food. This socio-cultural aspect also contributes to malnutrition. For all these reasons, it is normal that ACF is wondering about the reasons of such interactions and draw conclusions of such situations to better adjust its action.

Causes of death	Contribution to World Mortality 2002
HIV / AIDS	2 917 078
Diarrhoeal diseases	1 868 309
Tuberculosis	1 564 784
Low birth weight (perinatal condition)	1 268 765
Malaria	910 707
Maternal conditions	509 807
Protein-energy malnutrition	259 694
Iron deficiency anemia	136 672
Skin diseases	68 511
Leishmaniasis	51 094
Trypanosomiasis	47 717
Schistosomiasis	44 199
Vitamin A deficiency	22 883
Dengue	18 555
Intestinal worms infections	11 758
Iodine deficiency	6 530
poliomyelitis	830
trachoma	154
Onchocercosis	2

Fig. n°1 Estimated total deaths by causes – WHO 2002

1. DIARRHOEA

1.1   Frequency and Impact of Diarrhea

In developing countries, bacterial and viral gastroenteritis are the main causes of morbidity and mortality among children. In developing countries, the frequency of diarrheic diseases has been assessed through a meta-analysis[1] (Kosek, 2003) based on 27 studies on morbidity and mortality that can be due to diarrhea. The median of the frequency of diarrheic phases among children of less than 5 was 3.2 per child/year.
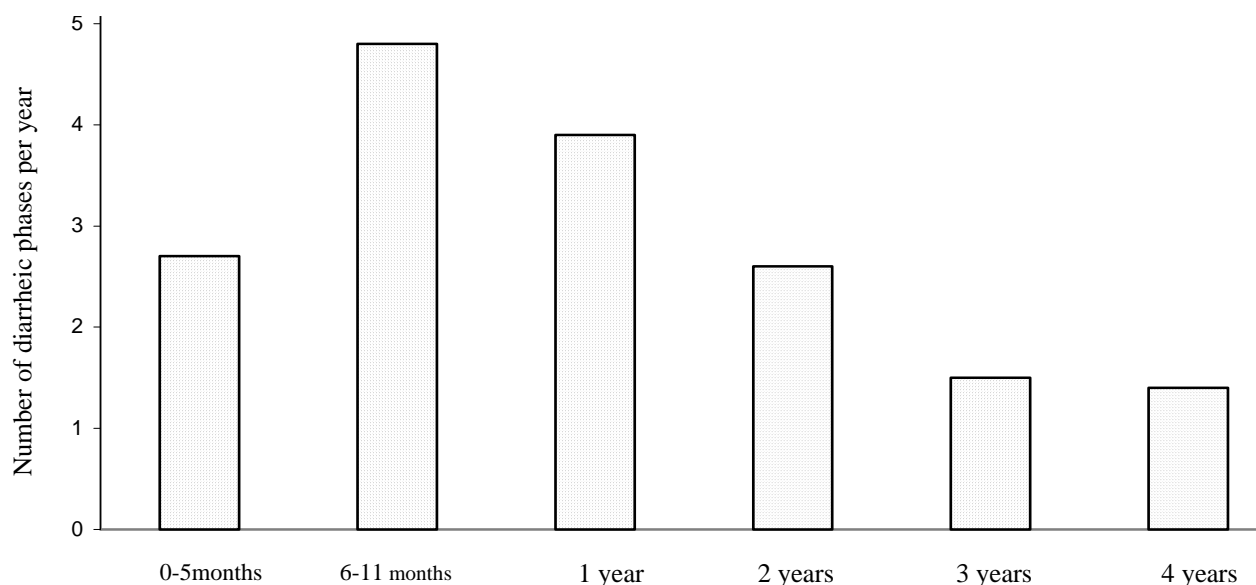

Fig. n°2   Frequency of appearing of diarrheic phases depending on age (according to KOSEK 2003)

Estimations on the mortality rate show that, in those areas, the number of children who died because of diarrheic diseases before the age of 5, was 4.9 per thousand per year, which in average value represents roughly one third of the total number of children's deaths, aged under 5.

So diarrhea is a major health issue in developing countries and we are going to study the various causes with the following frequency order:
-   Viral, bacterial and parasitic infections,
-   Antibiotics therapy, stress reactions, diseases related to lesions in the intestinal mucosa or to some endocrine diseases.

To get to simply know more about the performance of the intestinal barrier, please refer to Diskin, 2004 and about infectious diarrheas, please consult the web site: http://coproweb.free.fr

---

[1] A meta-analysis takes into account the hypothesis that several available studies on a given topic is a representative sample of all potential studies on that same topic.
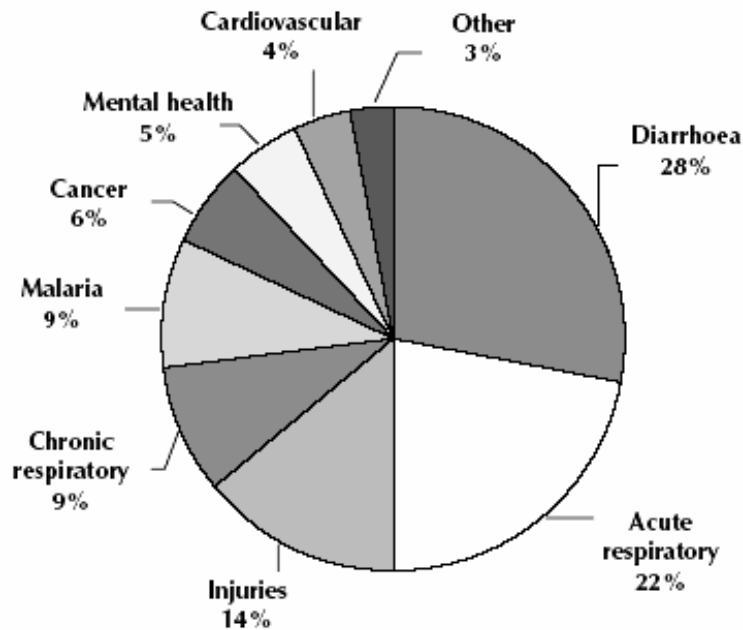
Fig. n°3   Distribution of death causes in developing countries
(according to CAIRNCROSS 2003)

1.2   Causes of diarrheas

1.2.1   *PATHOGENS*

1.2.1.1   Bacteria Infections

Several types of bacteria absorbed with contaminated food or water can be responsible for diarrheic phases. The bacteria most frequently met are *Campylobacter, Salmonella, Shigella & Escherichia coli etc….* Two medical journals very well documented (Leclerc, 2001 and Leclerc, 2002) published exhaustive lists.

1.2.1.2   Viral Infections

Since the 1940s we thought that gastroenteritis with unknown etiology had a viral cause. The first identified virus is the Norwalk virus (Kapikian, 2000) then the part played by the Rotavirus was later acknowledged because of its presence in the duodenal mucosa of diarrheic children.

In 1985, Zoysa and Feachem published a first article evidencing the seriousness of diarrheic diseases related to rotaviruses in developing countries. Their study based on measurements done on the field and on estimations showed that rotaviruses were responsible for 6% of the whole of diarrheic episodes and for 20% of the deaths of children under 5 due to diarrhea.

More recently (Parashar, 2003), a meta-analysis on children aged under 5 years in 10 industrialized countries and in developing countries over the 1986-2000 period, enabled to give a quantitative estimation on mortality due to viral gastroenteritis. In that analysis was included only the studies that could establish monitoring for at least one (1) year and which used reliable tests to identify rotaviruses: http://www.cdc.gov/ncidod/EID/vol9no5/02-0562.appA.htm.

Income scale	Total (x1,000)		Number of Deaths due to diarrhea	Number of diarrhea due to Rotaviruses	Death risk per diarrhea due to Rotavirus before the age of 5
	Births	Deaths			
Low	70,447	8,595	1805	361	1 out of 205
High	9,931	60	<1	<1	1 out of 48,680

Fig. n° 4   Morbidity and mortality due to rotaviruses: estimation among children aged less than 5 years and depending on the household's income (according to PARASHAR (2003)

The impact of diarrheas due to rotaviruses is similar in both industrialized countries and developing countries (representing 35% of severe diarrheas).

On the other hand, mortality is much higher when children are malnourished or immunodeficient and represents more than 80% of deaths due to diarrhea in the world (WHO</whr/2002/annex2 for 2001). Most of the studies mention that diarrhea appears at the age of 3 months-5 years with a peak between 7 to 15 months. As from the age of 3 to 4 years old, all children were potentially in contact with the disease.

Two recent papers presented the results of studies carried out in Africa and South America:
-    A study on viral diarrheas in young children in Nigeria (Audu 2002) showed that 33% of infections were due to rotaviruses, 7% to an adenovirus and 1% to an astrovirus.
-    An epidemiological study conducted in Brazil (Goïania, Goias) on infections due to rotaviruses showed that 27% of the fecal samples analyzed were positive in children suffering from diarrhea compared to 1.6% in children not suffering from diarrhea (Cardoso, 2003). This study, together with others mentioned in the paper, evidenced that rotaviruses are more common proportionally in boys than in girls. Infection seems to appear more often in children aged between 6 months to 2 years, as is the case in other countries. The author also takes into consideration the seasonal fluctuations (please read details thereabout further down).

All these viruses can spread locally through both fecal-oral transmissions. But it can also spread through dissemination: "foodborne viruses". One standard example is the contamination of huge quantities of food by only handling them with dirty hands or from an unidentified unique origin (Koopmans 2002 & Kaferstein, 2003).

Traditionally we thought that the causes of diarrhea would be reduced if we improved sanitation and hygiene (Curtis, 2000; Leclerc, 2002). However, these means are insufficient in themselves, since viruses and rotaviruses in particular can live for quite a long time on hard surfaces such as tables, toys, containers, etc and it is difficult to destroy them even with ordinary disinfectants.

A vaccine, which was approved by the FDA in 1998, protects 70% to 80% of children against infection due to one of the four most frequent rotaviruses. But quickly because of a serious risk of intussusceptions [2] (Wilhelmi, 2003), vaccination was interrupted.

At present the strategies employed to develop new vaccinations and the WHO general policy are studied to cure other types of diarrheas due to rotaviruses, Vibrio cholera, E. coli, Salmonella typhi, Shigella (Riddell, 2003).

---

[2] intussusceptions: the slipping of a length of intestine into an adjacent portion usually producing obstruction (Merriam-Webster definition) just like the finger of a glove turned inside out

1.2.1.3 Parasites

Diarrhea is also one of the many symptoms of an intestinal infection due to parasites. Whatever the health status of individuals, in endemic regions, it is very common to be faced with parasitic intestinal colonization. The most frequent parasites involved in a diarrheic diagnosis are *Giardia lamblia, Entamoeba histolytica & Cryptosporidium.* However the clinical impact of these intestinal infestations will mainly depend on the immune defense system of the host individual. When it is low, frequent and severe diarrheas appear. Malnutrition is one the major causes for immunodeficiency in developing countries. Frequent and severe diarrheas in undernourished children are caused by parasites, whereas well-fed children are healthy carriers of parasites (Gendrel, 2003). Diarrhea can be cured only after malnutrition has been treated as well as immunodeficiency of children.

1.2.1.4 General Comments on Pathogens

1.2.1.4.1 Seasonal Variations of Pathogens

Seasonal cycles of infectious diseases are assumed to have various causes: changes in atmospheric conditions, prevalence or virulence of the pathogen, reaction of the host's body. It would be interesting to understand the reasons for the seasonal variations of pathogens so as to better determine the periods during the year that require preventive care.

a) Bacteria

We know that high temperatures (i.e. during the summer season) contribute to the build-up of bacteria, as evidenced in the area of Karachi, to which one might add the monsoon negative impact on the waterborne sewage system that is usually insufficient for the rest of the year. Many studies were conducted on that topic and are mentioned in a meta-analysis on that topic (Alam, 2003).
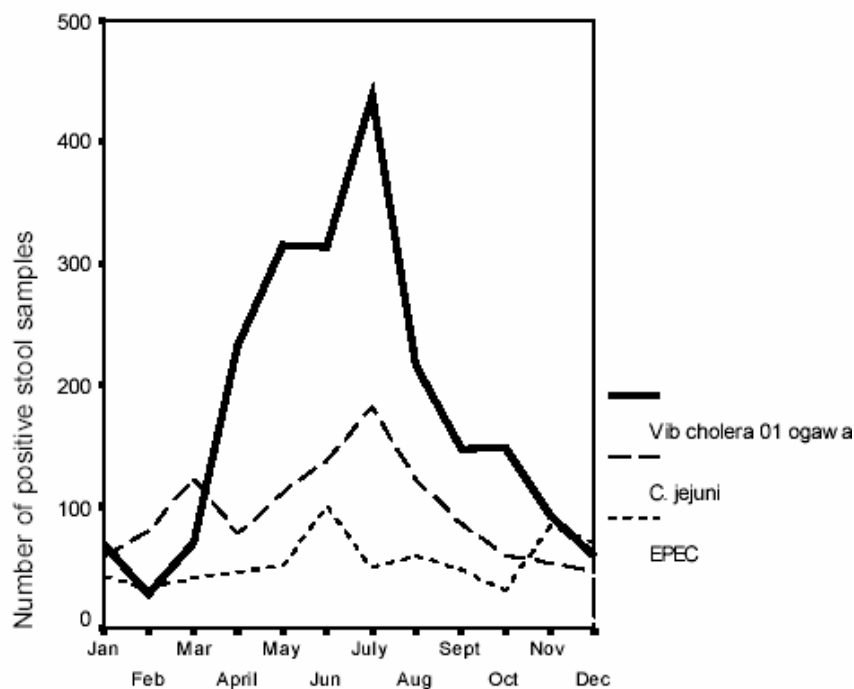

Fig. n°5   Seasonal distribution of pathogenic bacteria in Karachi stool cultures (Pakistan)
(Alam 2003)

b) Viruses

Infections due to rotaviruses can be seasonal ones and inversely correlated to temperature (Bittencourt 2000), but also to the humidity ratio during the dry season. In some areas of Brazil (Cardoso, 2003), the level of infections rises during the dry season (from April to August): during that period the moisture content of the air is rather low (approximately 50%); it is thus favorable to developing viruses. This same article quoted other references about the seasonal variations of infections due to rotaviruses in other areas in the world or in Brazil.

c) Parasites

No mention about seasonal variations for parasitic diarrhoeas, but for tick-borne diseases (Lyme disease) environmental studies showed that there was an increase in the population of mice responsible for transmitting the disease to human beings the year following the increase in available food because of climate events due to El Nino. It would then be possible to forecast periods at risk thanks to satellite monitoring of the changes in vegetation (Bradbury, 2003) hence prevention can be contemplated in due course.

1.2.1.4.2 Appearing of new pathogens

One important issue is the appearing of or the re-appearing of pathogens responsible for water pollution. A monograph devoted to this topic (WHO, 2003) stated the results of studies evidencing that several micro-organisms coming from feces either of human or animal origins or any other environmental sources not identified until then became pathogenic. The part played by water in transmitting these new infections was confirmed. Among these pathogens, we can mention cryptosporidium, Legionella, Escherichia coli O157 (E. Coli O157), rotavirus, norovirus (previously known as virus Norwalk), etc.
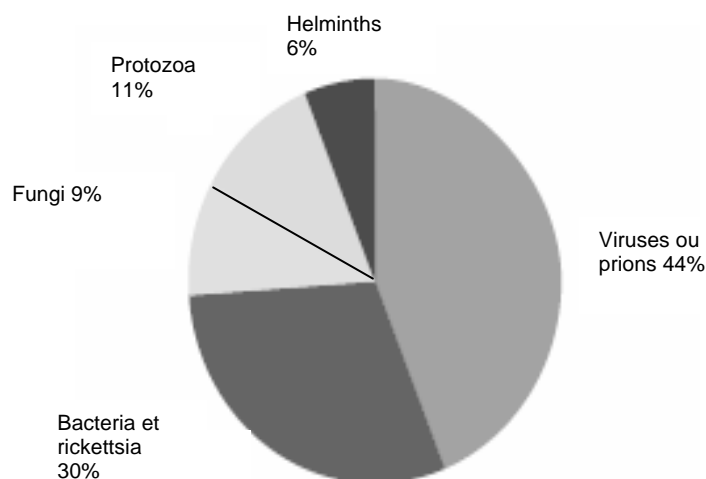
Fig. n°6 Distribution of new pathogens according to types of micro-organisms (adapted from Taylor, Latham & Woolhouse 2001)

1.2.1.4.3 The Part Played by Soils as Reservoirs

Recent works (Santamaria, 2003) insisted on the part played by soils as reservoirs especially with respect to many pathogens. These pathogens are more often than not transmitted by mouth or by feces. They can be bacteria, viruses, protozoa or worms such as helminthes.

Relationships between the soil and pathogens that are responsible for diarrhea or microbes relating to water-borne diseases (Leclerc, 2002) are not so far well-known. It is necessary to develop new methods to identify these disease agents and to study their environment, especially:

- How do long they survive in the soil?
- The part played by the various types of soils in protection or inactivation of pathogens.
- The inherent capacity of those pathogens to invade or colonize vegetables that are eaten raw.

1.2.2   *THE HEALTH STATUS OF INDIVIDUALS AS A FACTOR FAVORING DIARRHEAS*

1.2.2.1   Food Intolerance

Many adults have trouble digesting some food constituents, such as lactose in milk for example (please refer to http://www.niddk.nih.gov/). This intolerance is caused by lactase which is an enzyme with a variable activity ratio according to the various stages in life. This enzyme is present and is very active in children, then it declines permanently once the child has been weaned (Swallow, 2003).

1.2.2.2   Side Effects from some Medicines

A lot of medicines may involve diarrheas, especially antibiotics as well as antacids with magnesium, etc. We can include in this group of diarrheas osmotic diarrheas (Schiller, 1999).

1.2.2.3   Bowel Diseases

Inflammation and ulcers of the gastrointestinal tract, Crohn's disease, etc. Please refer to Kastin's meta-analysis, 2002, about the relationships between malnutrition and gastrointestinal diseases. Any intestinal dysfunction having a functional origin must be studied and compared therewith: the irritable bowel syndrome or functional dyspepsia (Feinle-Bisset, 2004) as well as chronic tropical enteritis very frequent in developing countries (Rosenberg, 2003).

2. LINKS BETWEEN DIARRHEA AND MALNUTRITION

Diarrhea can be considered as both the cause and the consequence of malnutrition: in fact diarrhea prevents children from catching up for stunting and malnutrition increases the frequency and the length of diarrheic episodes, constituting a vicious circle.

2.1 Infection and nutrition status

It is necessary to make the following two main preliminary methodological comments:

- Most of the studies relate to children aged less than 5 years. Nearly all of them give the weight-for-age, which is a measurement that does not distinguish between acute malnutrition and chronic malnutrition with a previous phase of acute malnutrition.
- The word « infection » is often used instead of diarrhea.

The direct relationship between infection and malnutrition is a rather new concept:
- A symposium on the "Treatment of severe diarrheic-induced malnutrition" took place during the "1st World Congress of Pediatric Gastroenterology, Hepatology, and Nutrition" (Boston Mass, USA, August 2000) during which Ashworth (2001) insisted on the "diarrhea-malnutrition-diarrhea" cycle.
- More recently a symposium was dedicated to "Nutrition and Infection, Prologue and Progress Since 1968" (Beisel, 2003) (Experimental Biology meeting, April, 2002, New Orleans). During that symposium the following issues were presented: the links between nutrition, malnutrition, infection and the immune system. Scrimshaw, 2003 gave the topic history and recalled the first monograph on interactions between nutrition and infectious diseases in 1968. He quoted the following: "It was gradually recognized from our INCAP studies that any infection worsens nutritional status. The most obvious effect of infection in poorly nourished child was on growth".

Most of the researches conducted on that issue since 1968 can be listed according to 3 main categories:
- Impact of diarrhea on the nutrition status, especially with respect to children.
- Risk factors of diarrhea.
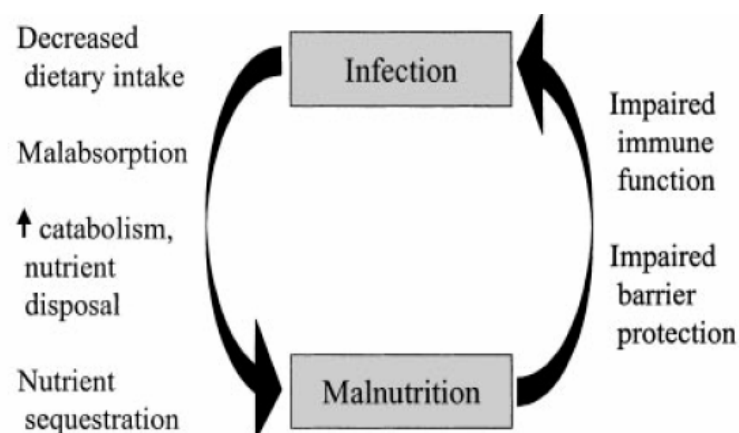- Therapies to be applied during and after an intestinal infection.

Fig. n°7   Relationships between infection and malnutrition (according to Brown, 2003)

The results of these studies led to drastic changes in the diarrhea treatment and in the public health policies. During that same congress, both Scrimshaw, 2003) and Keusch, 2003) insisted most often on the synergic relationships and also sometimes on antagonist relationships between nutrition and infection.

2.1.1 THE CONSEQUENCES OF INFECTIONS ON THE NUTRITION STATUS

Infections have a negative impact on the nutrition status because they reduce appetite (or food intake) and intestinal absorption, and at the same time they increase catabolism and the imprisonment of micronutrients that are necessary to growth and tissue synthesis. This is all the more so evident for any bowel infestation by worms since these are living on the food and nutrients eaten by children (Luong, 2003).

From mathematical models calculating the stunting proportion attributable to diarrhea (Martorell1980; Rowland 1988; Black1984), it appeared that ¼ to 1/3 of this stunting was due to intestinal infections.

2.1.2 IMPACTS OF NUTRITION ON INFECTIONS

Furthermore, malnutrition prones to infections because of its negative impact on the normal protecting barriers that the skin and mucosa are against any pathogens on the one hand, and on the reduction in immune defense on the other. A meta-analysis (Black and al., 2003) on the results of 10 longitudinal studies of children aged less than 5 years and born in various communities, evidenced that the delay in weight gain ("underweight") increases the mortality rate further to an infection.

The relative part played by the factor "weight lower than the average" is 61% for diarrhea, 57% for malaria and 53% for other infectious diseases.
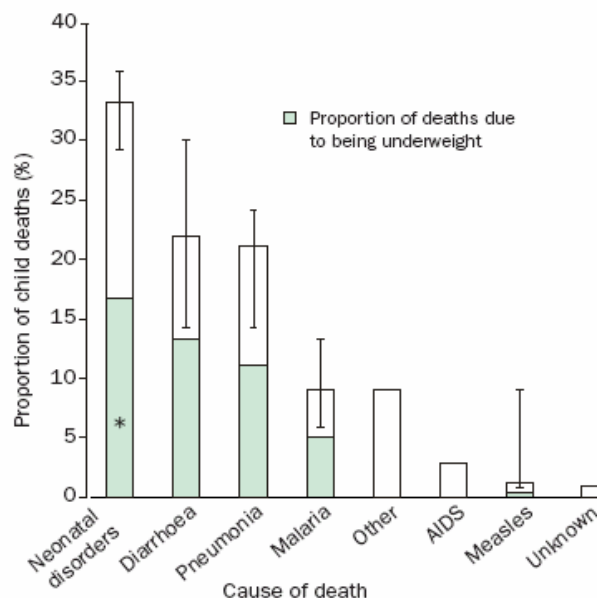

Fig. n°8 Relative impact of a « weight lower than normal » on the various causes of child mortality (according to Black 2003)

A survey carried out in Peru indicates that children aged under 3 living under food uncertainty conditions are at high risk of diarrhea appearance (Checkley, 2002): the more the ratio height/age and/or weight/age decreases, the higher the diarrhea incidence rate increases. This survey insisted on the diarrhea seasonal variations too; they were obvious in infants and they decreased when children get older. There is also an interesting debate on the importance of breastfeeding and on the relationship between the incidences of diarrhea with the child's age: diarrhea episodes are longer in young children.

Another survey conducted in North Vietnam mentioned that, when children received a balanced diet in suitable quantities, the frequency of diarrheas and respiratory infections decreases (Sripaipan 2002).

Finally, a meta-analysis (Rice, 2001) on malnutrition being an underlying factor of children mortality in developing countries gave an estimation of the impact of malnutrition on deaths due to diarrheas, acute respiratory infections, malaria, and measles. All these diseases are responsible for more than half of children's deaths worldwide. The strongest and the most frequent relationship were observed for deaths due to diarrheas and acute respiratory affections.

Next to this general opinion on the relationships between stunting, malnutrition and infections, some researchers are differentiating themselves and are debating about these relationships.

2.2 Controversy on the Relationships between Diarrhea and Growth

A small group of researchers and clinicians are questioning the supposed relationship between stunting and infection. For them only malnutrition can be held responsible for stunting.

The results of a survey carried out in 3 villages in Gambia in the late 1970s (Rowland 1977) evidenced the close relationship existing between stunting and diarrhea. Moreover, the results seemed to suggest that if we would get the number of diarrheic episodes lower, the weight curves could be harmonized (except during the rainy season also known as the "hungry season"). The same 3 villages were monitored during the following 15 years (1979-1993) and the two observation periods that were compared by authors (Poskitt, 1999). If they have observed a markedly decrease in the number and the severity of diarrheic episodes over the last period, on the other hand children's stunting remained the same. The authors came to the conclusion that the important reduction in the number of diarrheic cases had nothing to do with an improvement of their weight curve.

Further to this article two appreciations were issued (Bagott, 1999 et Weaver, 1999):

- For Bagott, stunting in this population would be partly due to "tropical enteropathy". This enteropathy would be persisting although individuals received supplementation in micronutrients and daily per capita energy supply in quantities suitable for growth. Entheropathy could have many causes: infections, deficiency in micronutrients, post-enteric food allergies, etc.

- Weaver recalls that growth depends on food intake, absorption and utilization of energy coming from nutrients. Malnutrition can be the result of dysfunctions of any one of the following factors (or a combination of them): insufficient food intake, deficiency in digestion and/or absorption of nutrients, increase in the needs or losses in the metabolism (mainly at gastrointestinal tract level).

Although it may be possible that growth could be the consequence of daily food supplementation ("super supplementation"), this did not imply that malnutrition be only caused by an insufficient food intake as supported by Poskitt, 1999. Nevertheless the results call for attention on the intake and the utilization of the various components of the energetic balance.

A survey led on children aged from 6 to 35 months in Bangladesh (Briend 1989) showed that the long-term effects of diarrhea on growth (both weight and height) were not significant. The deficiencies acquired during the diarrheic acute phase were not permanent and they disappeared after a few weeks. The conclusion was that all efforts done to overcome diarrhea would have no effect on growth.

An analysis of various papers challenging the part played by diarrhea in malnutrition (Briend, 1990) reports that some surveys mentioned that it was very much unlikely that malnutrition predisposed to the appearance of diarrheic episodes. But these data are not very clear about the fact that diarrhea might be one of the major causes of malnutrition. Some surveys examine the impact of diarrhea on food status over short time intervals and consequently it is not possible to tell if this impact is temporary or constant. To conclude on that, it appears that data suggesting that diarrhea precedes malnutrition are not very coherent: "*these studies do not show clearly that diarrhea precedes malnutrition. Inconsistencies between studies and lack of evidence supporting a biologically plausible mechanism also question the importance of diarrhoea as a cause of malnutrition*".

In Indonesia, the survey (Kolsteren, 1997) concluded that there existed no link whatsoever between infection (diarrhea, respiratory infection, fever) and growth during the infant's first six months, but that there was a relationship between growth and respiratory infections and not with diarrhea concerning children aged 6 to 11 months.

Another implicit argument: in Australia Rousham and Gracey, 1997 evidenced that between 1969 and 1993, the growth of children aged 0 to 60 months did not improve although the number of births of children with a weak weight decreased, as well as infectious diseases.

2.1.3.1 Reduction in Food Intake during Diarrheic Episodes

The reasons for reducing food intake during diarrheas episodes can be:

- Either due to the child itself: anorexia (either related or not to zinc deficiency that is very often is at the origin of diarrheic episodes) or a child too weak to feed itself.

- Or the result of forced restriction because of default caring of children (Ashcroft, 2001): up the 1980s it was common to leave children on a "starvation diet" or not breastfeeding them during diarrheic episodes (Kaur 1994); please refer Brown K., 2003 for the history of this.

The first studies conducted in Panama (Mata, 1992) showed that children's weight gain was influenced by infectious phases.

Observations done in Guatemala (Martorell, 1980), Western Africa (Rowland, 1988) and Bangladesh (Black 1984) were at the origin of mathematical models to estimate the proportional deficiency in growth due to diarrhea and approximately 1/3 to 1/4 of the decrease in growth could directly relate to intestinal infections (Brown K., 2003).

A survey conducted in Peru (Brown, 1990) evidenced that during diarrhea or fever phases, breast-feeding children reduced their energetic consumption by approximately 6%. A reduction

of 20-30% in the consumption of substitution milk could be observed in children that were not breastfed.

A survey in Zambia concerning a farming population of preschool children (6-9 months and 14-20 months) put forward the fact that children suffering from stunting absorbed less energy than other children (Hautvast 1999). However the authors of this survey noticed that the quantity of energy absorbed per kilo of children's weight was identical for both groups.

2.1.3.2 Reduction in Intestinal Absorption (Malabsorption)

In Gambia (Lunn, 2000, ID34) showed that stunting for 43% of children aged under 15 months was due to enteropathy. Intestinal villi atrophy reduced the assimilation of lactose and other nutrients. Moreover lesions in the mucosa barrier could induce translocations of macromolecules in the blood and thus creating local inflammations and generally inappropriate immune reactions[3].

A study conducted in Chile (Castillo-Duran 1988) during acute diarrheic episodes showed that depletion in zinc and copper occurred (please read below the importance of those micronutrients).

Furthermore, some food supplements composed of plants and administered to children after weaning could also reduce food absorption (more particularly those containing tannin and lectines could damage intestinal mucosa and be responsible for diarrheas).

In addition, food could be contaminated by pathogens (Mensah, 2003) and hence bring about diarrheas.

2.1.3.3 Infections and Immune System

During the same symposium « Nutrition and Infection, Prologue and Progress Since 1968" held in 2002 (Experimental Biology meeting, April, 2002, New Orleans), Keusch, 2003 reviewed and traced the history of present knowledge on relationships existing between malnutrition, infection and immune system.

Since only 1980-1990, malnutrition -even moderate malnutrition- has been acknowledged as being responsible for weakening the immune system. The changes occurring in the immune defense system described in the developed countries and concerning some in-patients (trauma or surgery) or elderly people (anorexia further to taking medicines) could be compared to those observed in undernourished children or adults living in developing countries.

A journal of Bhaskaram (2002) reviewed the relationships between malnutrition, infection and immune system in developing countries. A book was recently published about "Nutrition and Immunology », 1999, a review written by Hoerr (2000).

---

[3] A review on that topic and a bibliography: Kastin & Buchman, 2002. One can read clear and simple explanations on the intestinal barrier in the presence of infectious diarrheas at the following Website: http://coproweb.free.fr

---

Here is an example of misinterpreting data on the field and later adjusted.

Moore (1997) suggested that, during pregnancy, the impact of malnutrition on the fetal development of the immune system would be responsible for the excess mortality of the new-born babies at some specific times in the year. It was observed in Gambia and it showed early mortality among infants (being 10 times higher than normal) during the "lean period" (July-October) that corresponds to the rainy seasons and during which the reserves of the last crop are at their lowest level. For adults, that corresponds to a hard working period in the fields. These factors are cumulative and lead to create intra-uterine stunting and a decrease in infants' and children's growth. These consequences disappear when mothers' malnutrition is reduced. The authors suggest that the intra-uterine sensitivity of the immune system to malnutrition would be responsible for the mortality rate seasonal variation

However, this interpretation is put into question in a second paper written by the same authors (Moore, 2001). There seemed to be no known relationship between the immune function and the season of the birth.

Nevertheless the mortality due to infectious diseases is 10 times higher in children born during the rainy seasons and aged over 15 (please refer to Ceesay, 2003 too).

Lastly, epidemiological data revealed that infants' low weight at birth was associated to a high infant mortality. In Brazil, Victora (1998b) showed that children with a low weight at birth were twice as much at risk of dying from diarrhea, 1.9 times as much at risk of dying from respiratory infections and 5 times as much at risk of dying from infections than children with a birth weight >2,500 gr.

2.1.3.4 Micronutrients and Immune Answer

The role of micronutrients in appropriate immune reactions to aggressions has been now fully accepted (Bhaskaram 2002, Erickson 2000). The meta-analysis of Stephenson (2000) made a list of the four most important types of malnutrition in the world:
- Malnutrition due to a deficiency in the level of intake.
- Iron deficiency and anemia (IDA).
- Vitamin A deficiency (VAD).
- Iodine deficiency diseases (IDD).

The analysis took into account comprehensive and regional distribution, the age and the suffering groups of individuals or individuals at risk. The part played by zinc deficiencies in malnutrition and infections were also looked through.

Finally a report from the UNICEF, 2004 reviewed the distribution of the various types of deficiencies worldwide.

a) Vitamin A Deficiency

A lot of studies carried out on various types of populations evidenced a reduction in children mortality rate when these children received a diet with vitamin A (Grotto, 2003). Many food aid projects based on these data included Vitamin A supplementation in their medical support programs.

Based on the published literature from 1966 to 2000, the Grotto meta-analysis concluded in a negative way and indicated that the intake of vitamin A had no effect on the diarrhea incidence and slightly increased the risks of respiratory infections. Vitamin A action, controlled by Keusch, 2003, reported several potential explanations to these disappointing results:

- Vitamin A deficiency produces a keratinisation of lung epithelium which involves a reduction in mucosa secretions with the consequence that the epithelium has less capacity to destroy the pathogenic bacteria.

- Vitamin A (and all the other rétinoides) regulates the expression of genes responsible for the synthesis of proteins essential in immune defense.

However, save for measles, the processes involved in the increase in the mortality rate due to vitamin A deficiencies have not been clearly explained yet.

b) Iron Deficiency

It is difficult to bring down IDA (Iron Deficiency and Anemia) (Beinner, 2003). Iron deficiencies are responsible for anemia from which one third of the world population suffers. Recent estimates stress that these types of anemia are responsible for one third of the neo-natal mortality and for 10% of maternal mortality during delivery (Ezzati, 2002; Murray, 2002).
Iron deficiency reduces the cognitive development and the results at work (Ezzati 2002, Stephenson 2000, Martins et al, 2003)

Observations made in India (Majumdar 2003) led us to be very careful as to automatic iron supplementation: in fact although an iron supplementation given to deficient children can lead to weight and height gain, when given to children having no deficiency, iron intake might result in a loss of weight and stunting. A study discussed the possibility of prevented any such deficiency by simply cooking meals in iron vessel (Geerligs 2003).

c) Zinc Deficiency

The impact of severe zinc deficiency has been well known since the 1960s, but the consequences of a little deficiency in zinc (the most frequent) have just been known (please refer to the report of Golden, 2001).

Zinc supplementation improves children's growth, reduces the incidence of diarrhea, malaria and pneumonia; it also reduces children's mortality rate (Black, 2003; Bhutta 1999). All in all approximately 800,000 children die from zinc deficiencies each year (Murray, 2002; Ezzati, 2002).

It has often been evidenced that a zinc deficiency leads to limiting weight gain, but the effects of zinc supplementation on patients or populations are still not known because no simple test exists enabling to measure the zinc rate in the body. Moreover, growth is the result of many factors and zinc itself also influences other body functions than growth itself. Many recent papers mentioned that zinc reduced infection risks and had a positive impact on growth.

Roy, 1990 indicated an increase in children's growth by 25% when they took zinc supplementation during diarrheic phases. A decrease in children's mortality due to diarrheas or pneumonia was also reported by Tomkins, 2000.

A meta-analysis carried out on data from various countries Bhutta, 1999, showed that the occurrence of diarrheas, pneumonia and malaria decreased further to zinc supplementation.

More recently Black (2), 2003, showed that zinc played a great part in the prevention of infections, diarrheas, respiratory infections and probably on malaria, from 11 laboratory trials performed. He also cited the results of a study carried out in India by Sazawai, 2001 evidencing a reduction of about 68% in the mortality rate of children deemed "small compared to their gestation age" when they are given zinc supplementation at the age 1 to 9 months. A study (Patel, 2003) analyzed the advantages of zinc and copper supplementations with respect to the cost involved in treating acute diarrheas in children aged 6-59 months.

There have been no statistically significant differences about the efficiency of diarrhea treatment (especially quick impact and reproducible aspect) in children receiving supplementation and children being treated the normal way (taking into account the number of cases surveyed from a statistical point of view).

Pregnancy has also been studied several times. The article of Osendarp, 2003 did an analysis on the results of 8 trials carried out in several developing countries (meta-analysis). If in developed countries the results were not satisfactory, in developing countries zinc supplementation during pregnancy had positive effects on neonatal morbidity and on infant infections. Nevertheless the authors concluded that it was necessary to do new researches to assess the advantages of zinc intake during pregnancy on a larger scale.

d) Iodine Deficiency

For quite a long time, we knew that iodine deficiency during pregnancy could lead to spontaneous abortions and to cretinism (Glinoer, 2003). Over 2 milliard people live in regions with low iodine. Until the 1990s a deficiency in iodine (IDD: Iodine Deficiency Disorders) affected nearly one third of the world population.

This deficiency is mainly causing brain injuries (motricity, etc.) and more or less important mental handicaps. In fact we need iodine to synthesize thyroid hormones involved in the regulation of body cell metabolism. They also play a major part in the development of nearly all organs, including the brain, during the fetal period and the postnatal period (Delange, 2001).

This led us to prepare highly efficient programs for the distribution of iodized salts in several regions. François, 2002, made a list of all the results collected in 128 pays. Further to the resolution adopted during the Children World Summit, an iodine supplementation program was decided upon for the affected countries. Ten years later, 70% of the affected populations received iodized salts and we observed an extraordinary reduction in the symptoms due to the deficiency (Delange and Lecomte, 2000).

3.1.3.5 Health Protection due to Breast-feeding

If all authors agreed on the positive action of maternal breast-feeding on children's health, there are different opinions about the optimal time during which children have to absorbed maternal milk exclusively: possible recommendation on exclusive feeding with mother's milk during 4 to 6 months or until aged 6 months?

What Rowland, 1986, called: `weaning's dilemma' in poor countries. The point was to choose between the protective effect of mother's milk against infections or the risk that, beyond 4 months, there was not enough mothers' milk and/or that its quality was not good enough to cover infants' nutrition needs.

Two meta-analyses by the Cochrane and WHO, 2000, studied this question:

- A meta-analysis was carried out on several data bases (with 2,688 references from 1966-2000) (Kramer 2002). Clinical studies were selected as well as observations that compared the sanitation status of either child or mother after a six-months' breast-feeding period exclusively or after a period of only 3 to 4 months with a diet composed of both breast-feeding and food supplementation. The studies were classified according to the type of analysis (control trials/observations), the origin (developed countries / developing countries) and the length of the breast-feeding period (3 to 7 months or more). Quality criteria of the various studies were set by the two authors in accordance with the double blind method. The authors concluded that they did not find any objective reasons to support the assertion that there existed *"weaning's dilemma"*: children being exclusively breast-fed during 6 months were less subject to morbidity due to gastrointestinal infections than children who received mixed feeding since the age of 3-4 months. There was no evidence of growth deficiency in children exclusively breast-fed during 6 months in both developed and developing countries. Moreover the mothers of these children (exclusively breast-fed >6 months) had longer lactation amenorrhea. Under the condition that children are monitored in order to avoid missing any individual problems (such as insufficient growth or others), the data showed that there is no contra-indication for recommending breast-feeding during the first six months of life, and whatever the level of development of the country of origin. Nevertheless authors are careful and they insist on carrying out other randomized studies on a large scale to be sure that they are not going to miss any negative impact on children's growth.

- In 2000 a group of experts belonging to WHO studied the impact of breast-feeding on the prevention of child's mortality; it showed clearly that breast-feeding protects infants at risk against respiratory and diarrheic infections (WHO, 2002). The data in the literature published between 1980-1998 was carefully looked at in a meta-analysis by this group. The analysis evidenced that children who were not breast-fed were likely to die 6 times more from an infection in the first two months of their life compared to those being breast-fed. This protection is reduced over the time. Three studies conducted in three different continents showed that, during the first year in life, breast-feeding revealed to protect the child from infections. In the course of the second year, the results were not so clear, but they however suggested that children were somewhat protected (however it is much more difficult to believe that children of that age were fed with or drank their mother's milk only).

Therefore a study conducted in rural areas of Senegal (Simondon, 2001) showed that children being breast-fed over a long period of time (up to 3 years) have seen their growth capacity improved and become rather linear.

With respect to the experts' results, the World Health Assembly (references relating to the works of WHO) issued a resolution requesting that the member nations promoted exclusive breast-feeding for at least 6 months. During that period infants were fed with only mother's milk (with an exception for vitamins drops in medical syrups, mineral supplementation or medicines) (WHO, 2000 2001 2002).

Finally, an article from Bhandari, 2003 published the randomized study done in India, in Haryana State which is a developing area with mother-and-childcare centers. Under such circumstances, the promotion of exclusive breast-feeding up to the age of 6 months was feasible and reduced diarrheic risks; it did not imply stunting either. This article was interesting because the authors experimented the recommendations directly on the field, their feasibility, their efficiency and the absence of any danger from WHO guidelines.

In a leading article, two of the experts having participated to the drafting of WHO recommendations (Black & Victora, 2002) were very happy with the guidelines, but they insisted on two points that had never been discussed:

- One issue was zinc and iron supplementations in infants' food: it appeared that in some cases –especially for children with low weight at birth- these minerals were present in small quantities in the mother's milk and thus could not be sufficient for child needs. Thus, the UNICEF recommended zinc and iron supplementations as from 2 months old along with strict breast-feeding.

- The second issue related to the contamination of HIV virus through the mother's milk.

a) Breast-feeding and Transmission of HIV Virus

We know that the HIV virus can be transmitted through the mother's milk.

In countries with low child mortality and where reliable food substitutes were available at a rather low price, it was recommended to avoid breast-feeding.

On the contrary in very poor regions, child mortality due to diarrheas, pneumonias and other infections would certainly increase if mother's milk did not protect infants. A randomized study conducted in Kenya (Mbori-Ngacha, 2001) on HIV-positive mothers concluded that the incidence of diarrheas or of respiratory infections was identical for children (<2 years) fed with mother's milk or with milk substitutes. But the virus transmission rate was lower in children >2 years fed with milk substitutes. The authors concluded that, even in poor areas, it was possible to feed children with milk substitutes without any vital risk under the condition that mothers received appropriate training thereto and that water of good quality was supplied. This article brought up controversy (Guay, 2001 and Kent, 2001). In a highly criticized comment, Guay declared that in very poor regions breast-feeding until 6 months old followed by quick weaning seemed to be the best solution. This point of view was also developed by Tompson, 2002).

In an article (Kourtis, 2003) called "*Breast milk and HIV-1: vector of transmission or vehicle of protection?"* the authors indicated that breast-feeding was responsible for a contamination rate of 40%. Yet many children were not contaminated although they had known sustained exposure to the virus. The authors supposed that immune factors might be present in the mother's milk which could have explained protection against the disease.

b) Local Practices and WHO Recommendations

Sometimes it seems that in some areas the WHO recommendations might be conflicting with ancestral principles and local practices.

An anthropologic study by Sellen, 2001 compared the official recommendations to the tradition of feeding children in populations of non-industrialized regions. The study dealt with ethnographic and demographic results gathered between 1878 and 1998 and concerned 113 populations. Among the data analyzed we can mention: when children started breast-feeding, the use of prelacteals (which are substances absorbed prior to the first breast-feeding), the loss of colostrums, early introduction of water, herbal teas and nutritive liquids, and early or late feeding of solid or semi-solid food, etc.

In most of the 113 populations studied, Sellen, 2001 observed that the average age of first intake of liquids other than mother's milk (4.5±6 months) or solid food (5±4 months) and the breast-feeding length of time (29.0+/10 months) correspond with the optimal weaning age as recommended by WHO.

3. WATER AND SANITATION AND HYGIENE

Millions of people -most of them being children- are dying of diseases which are directly linked to the most basic hygiene rules (Kosek, 2003) (Pruss, 2002).

Some practical actions on hygiene, sanitation and waterworks proved that it was possible to reduce the frequency and economic impact of diseases. Many studies conducted at community or family levels in developed or non-developed countries, showed that the increase in water quantities available in households, the improvement of its bacteriologic qualities thanks to appropriate treatment on the water catchment site, or the modification of the storing method or utilization, reduced the risks of infections linked to water and especially the diarrheic diseases.

The results relied on factors related to technology, environment (local practices) and to demography (Thompson, 2002). But a major current issue was the appearance or the re-appearance of pathogens responsible for water pollution.

3.1 How to Interrupt the Bi-directional Relationship Infection/Malnutrition?

3.1.1 HISTORY OF THE IMPACT OF ACCESS TO WATER AND TO SANITATION

In the 1960s few data existed regarding the issues of access to water in developing countries. In the 1970s the World Bank "would" have discouraged the progress of any research about the relationships between sanitation and health (Juery, 2003).

In the early 1980s, Blum and Feachem, 1983, dedicated a study to assessing the impact of sanitation on infections, and especially on diarrheas. They however showed that all the articles published till then included methodological errors and that new assessment should be necessary to get restricting data. The same year, a workshop held in Bangladesh concluded that it was necessary to go back to previous epidemiological studies on relationships between sanitation and health, but on the condition that some methodological rules be respected.

More recently (Heller, 2003), a meta-analysis of 256 epidemiological studies carried out between 1983-1995 listed articles aiming at evidencing the relationship between sanitation and health.

Most of the studies (conducted in rural areas) may be summarized as follows:
- 198 (77%) to the impact of the improvement of the access to water on the health
- 146 (57%) were conducted in Asia and Africa
- 107 (42%) to the part played by waste water disposal
- 105 (41%) chose diarrhea as the assessment criteria
- 44 (17%) on draining and on hygiene habits
- 12 (5%) on the presence of disease vectors
- 4 (2%) more particularly focused on the waste disposal

For over ten years now, among researches using the case control study methodology[4] those using prospective analysis techniques: 64 (25%) or transversal analysis: 53 (21%) prevailed.

---

[4] Case control study: the "cases" are children suffering from diarrheas and the "control cases" are children aged less than 5 years and selected at random.

The same authors (Heller, 2003) stated their results of studies carried out in Brazil on the impact of sanitation and of the incidence of diarrheas in children under 5 years living in urban areas. The technique was the case control study (997 'cases' compared to 999 'control cases'). After some adjustments, the variables associated significantly with the presence of diarrheas were: washing fruit and vegetables, existence of stagnant water in the streets, storing and destruction of wastes, the conditions of water storage in the household, disposal of feces, flooding of homes. The assessment of relative risks could reach 2.87 (hygiene of fruit and vegetables). The authors concluded that it was possible to develop and implement a proper model enabling to set the priorities for an action in the sanitation and environment field.

rang	Variable	Comparision	RR adjusted, confidence interval
1	Fruit and greens hygiene	Other care x disinfection	2.87 (1.61-5.10)
2	Mother's religion	No x yes	2.58 (1.18-3.03)
3	Superficial presence of wastewater in streets	Yes x no	2.38 (1.87-3.03)
4	Refuse storage	Other x no storage	1.97 (1.55-2.50)
5	Domestic reservoir	No storage x covered and cleaned reservoir	1.91 (1.37-2.67)
6	Domestic reservoir	Matériel de stockage x réservoir couvert et nettoyé	1.91 (1.01-3.60)
7	Child's age	Continuous variable	1.81 (1.63-2.02)
8	Faeces disposal from swaddle	No swaddle use x toilet/latrine disposal	1.65 (1.21-2.24)
9	Refuse disposal	Vacant stream disposals x frequent public collection	1.61 (1.11-2.34)
10	Children number	Continuous variable	1.58 (1.28-1.96)
11	Near stream existence	No x yes	1.57 (1.22-2.01)
12	Faeces disposal from swaddle	Other x latrine disposal	1.50 (1.04-2.19)
13	Refrigerator's ownership	No x yes	1.41 (1.12-1.76)
14	Cockroach presence	>3 months a year x < one month a year	1.40 (1.12-1.76)
15	Flooding in plot	Yes x no	1.39 (1.09-1.76)
16	Mosquito presence	All time x <6 months a year	1.37 (1.08-1.73)
17	Refuse collection frequency	2 times a week x 3 times a week	1.33 (0.99-1.79)
18	Domestic water reservoir	Covered and not cleaned x covered and cleaned	1.07 (0.82-1.40)
19	Domestic water reservoir	Uncovered and cleaning x covered and cleaning	1.02 (0.56-1.88)
20	Domestic water reservoir	Uncovered and not cleaned x covered and cleaned	0.94 (0.40-2.20)

Fig. n°9   Impact of hygiene conditions on health (according to HELLER 2003)

In 2003, at the Kyoto Summit, it was acknowledged that efforts should not only concentrate on the issue of water quality, but also on hygiene and sanitation (wastewater disposal). Governments must develop strategies with the target of reducing by 50% the number of people who have latrines by 2015 and by centering aid work on basic hygiene principles and more particularly hands washing. Refer to the leading article of (Curtis and al. 2003), (Curtis, 2003), on that topic.

Intervention	Reduction in diarrhoeal risk (%)
Hand washing with soap	47
Sanitation	36
Hygiene promotion	35
Improve water quantity	20
Improve water quality	16

Fig. n°10   Effectiveness of specific interventions against risks of diarrheic diseases
(Curtis & Cairncross 2003)

An IRC monograph (Appleton, 2003) summed up the various means to implement in order to effectively promote the various programs in accordance with local practices (with examples from Africa, Asia and Latin America). Many studies examine the Global Burden of Disease (GBD). It consists in assessing the respective 'weight' of major diseases and their causality at global and regional levels (Ezzati, 2002 and Powles, 2003) ; (Cairncross and al., 2003); (Kosek, 2003) comments.

3.1.2 IMPORTANCE OF HAVING ACCESS TO WATER

One of the topics of many reports was the importance of having access to water (IFPRI, 2001). Pronk, 2003, insisted on the role of sanitation and health education; he also insisted on the limited capacity of "liberal" systems to solve such issues. No access to water or poor access to water greatly affected height and weight gain of children. One important point was to know whether this was a permanent effect or a transitional one; Hoddinott, 1997 wrote a monograph on the impact of improving access to water on health and people's income in developing countries. It quoted the conclusions already mentioned in Martorell's book (1995) about developing countries: the reasons responsible for stunting could be seen within the first two years of children life. Studies carried out in Egypt, Kenya, Mexico, etc. showed that the main part of stunting occurred before the age of 2. Other studies evidenced that poor Indian children suffering from stunting at the age of 5 would have a small height when they become adults. Other studies done in Guatemala also indicated maturational lag in the first years of life. Young boys and girls older than 5 cannot catch up for stunting. If this is exact, the impact of no access to drinkable water in childhood will still persist all life long. Stunting during childhood can be noticed when becoming adult and it is often related to early death because of an increase in cardiovascular risks and lung damage. In the case of women there is an increased mortality risk of either mother or child during delivery because of a narrow pelvis (World Bank 1993). All these data are taken from Hoddinott's review (1997).

Percentage in diarrhoeal morbidity

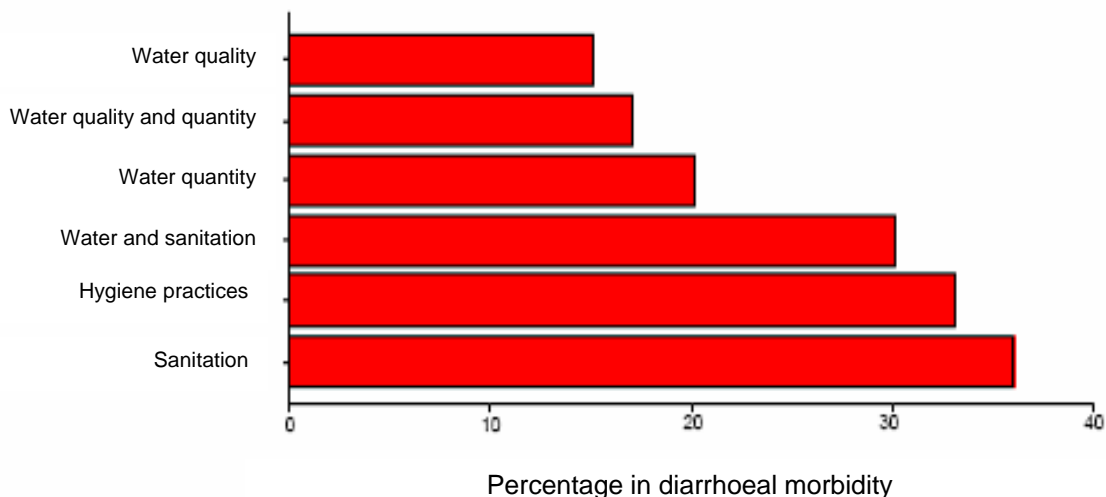*Fig. n°11 Impact of water sanitation and hygiene on diarrhoeal morbidity (Hoddinott, 1997)*

3.1.3   HOW TO DEFINE THE NEEDS IN DRINKABLE WATER

The access to drinkable water has been acknowledged by everybody as a fundamental right. In 2000 it was established that 1/6 of the inhabitants on the planet had no access to drinkable water within a reach of 1,000 meters from their home (UNICEF, 2003).

3.1.3.1 Quantity of Water Necessary

It has never been clearly defined the average quantity of water necessary to keep somebody in good health (Howard, 2003). This basic quantity of water necessary includes the water for keeping the body moisturizing (drinkable water) and the water for basic hygiene. It would seem that 7 liters of water be the least to remain in good health (with moderate physical activity at room temperature a little above average). The table below summarizes the warning levels depending on the various criteria:

Service level	Access measure	Needs met	Level of health concern
No access (quantity collected often below 5 l/c/d)	More than 1000m or 30 minutes total collection time	Consumption – cannot be assured Hygiene – not possible (unless practised at source)	Very high
Basic access (average quantity unlikely to exceed 20 l/c/d)	Between 100 and 1000m or 5 to 30 minutes total collection time	Consumption – should be assured Hygiene – handwashing and basic food hygiene possible; laundry/ bathing difficult to assure unless carried out at source	High
Intermediate access (average quantity about 50 l/c/d)	Water delivered through one tap on-plot (or within 100m or 5 minutes total collection time	Consumption – assured Hygiene – all basic personal and food hygiene assured; laundry and bathing should also be assured	Low
Optimal access (average quantity 100 l/c/d and above)	Water supplied through multiple taps continuously	Consumption – all needs met Hygiene – all needs should be met	Very low

Fig. n°12   Domestic water quantity x level of health concern (Howard , 2003)

3.1.3.2 Quality of Water

The notion of "quality of water consumed" is essential: we know that polluted water can be responsible for diarrheas. Watching carefully at the quality of water is of the utmost importance to prevent any outbreaks in industrialized countries too. We must not forget that water may contain chemicals that can poison people: arsenic in Bangladesh, fluorine in India and China, nitrates in many regions in the world. There is no such thing as zero risk for these issues; for each case, each acceptable level of risk must be defined.

3.1.4   CLASSIFICATION OF WATERBORNE INFECTIONS

Risk factors relating to the association of «water, sanitation and hygiene» are many, interrelated and responsible for several diseases.

Among the potential diseases those fecal-oral transmitted diseases are the most frequent. The first study concerning the impact of domestic water on health was carried out by two geographers in Africa: "Drawers of Water, Domestic Water Use in East Africa", (White, 2002). This first article has since been often quoted as "DOWI" standing for Drawers Of Water I (1st version). TDOWI gives the definition of several types of contaminations and lists waterborne infections according to their mode of transmission rather than to the type of responsible viruses or to the effects of pathogens on individuals.

3.1.4.1 Classification DOW I

The authors of **DOWI** made a distinction between four types of transmission:

- **"Water-borne diseases"** correspond to traditional causes of waterborne outbreaks: for instance in sub-Saharan Africa, cholera and typhoid are transmitted through contaminated water

- **"Water-washed diseases"** are the result of too little quantities of water consumed for domestic hygiene. Here the most important is quantity and not quality. More often than not skin diseases and ophthalmic diseases, but also diarrhoeas. DOWI does not give a direct definition of these diseases: "infections which frequency or severity can be reduced thanks to an increase in the quantity of available water no matter its quality" (DOWI p.169, quoted by Thompson, 2001 in Drawers of Water II).

- **"Water-based diseases"** are due to pathogens transmitted by aquatic organisms. During the incubation phase, those diseases are transmitted through a lot of contacts or drinking of contaminated water, for instance taking baths or washing clothes. The two main diseases in sub-Saharan Africa are schistosomiasis and guinea worm disease.

- **"Water-related insect vectors diseases"** are the diseases spread by insects that develop or feed themselves in water, such as malaria, dengue or 'river blindness'.

On top of this classification, this monograph is of the utmost importance because it suggested that it was at least as important to increase the quantity of water per head as to increase its quality and that the creation of a new and additional water point, although remote from houses, had little impact on water quantities taken back to the homes. It also stressed how important individual initiatives were so as to provide local and targeted solutions: "The way people respond to present and improved supplies and the effect this has on community health and welfare should be examined for the whole range of theoretically possible improvements. Increased volume of use does not necessarily bring proportionate gains in health. Neither does the construction of additional safe supplies necessarily result in increased use by those people who most need them".

3.1.4.2 Classification DOW II

A second study (Drawers of Water II, DOWII) carried out in the same regions reused the previous data provided by DOWI (Thompson, 2001). This study changed DOWI classification by preferring the mode of transmission to the diseases. In fact a disease can have several modes of transmission. This is very important if we wish to control diseases by anticipating prevention actions over the environment rather than proceeding with vaccination campaigns or the treatment of patients.

The new classification set forth by **DOWII** is as follows:

- *"Fecal-oral" transmitted* diseases (they can perhaps be water-borne or water-washed) either Low infective dose: cholera, typhoid, or High infective dose: diarrheas due to amoeba and bacteria, ascariasiosis, gastroenteritis, hepatitis, paratyphoid, Enterovirus and hookworm.

- **"Water-washed" transmitted** diseases: (strictly) skin or eye infections (trachoma, abscesses and ulcers, scabies, conjunctivitis, yaws (tropical form of treponematosis), typhus transmitted by insects or spiders.

- **"Water-based" transmitted** diseases either through the skin (schistosomiasis or bilharzias), or through ingestion (guinea worm disease).

- **"Water-related insect vectors" transmitted** diseases: Breeding in water: malaria, onchocercosis, yellow fever, filariasis**,** dengue, and several infections due to arboviruses. Biting near water: trypanosomiasis.

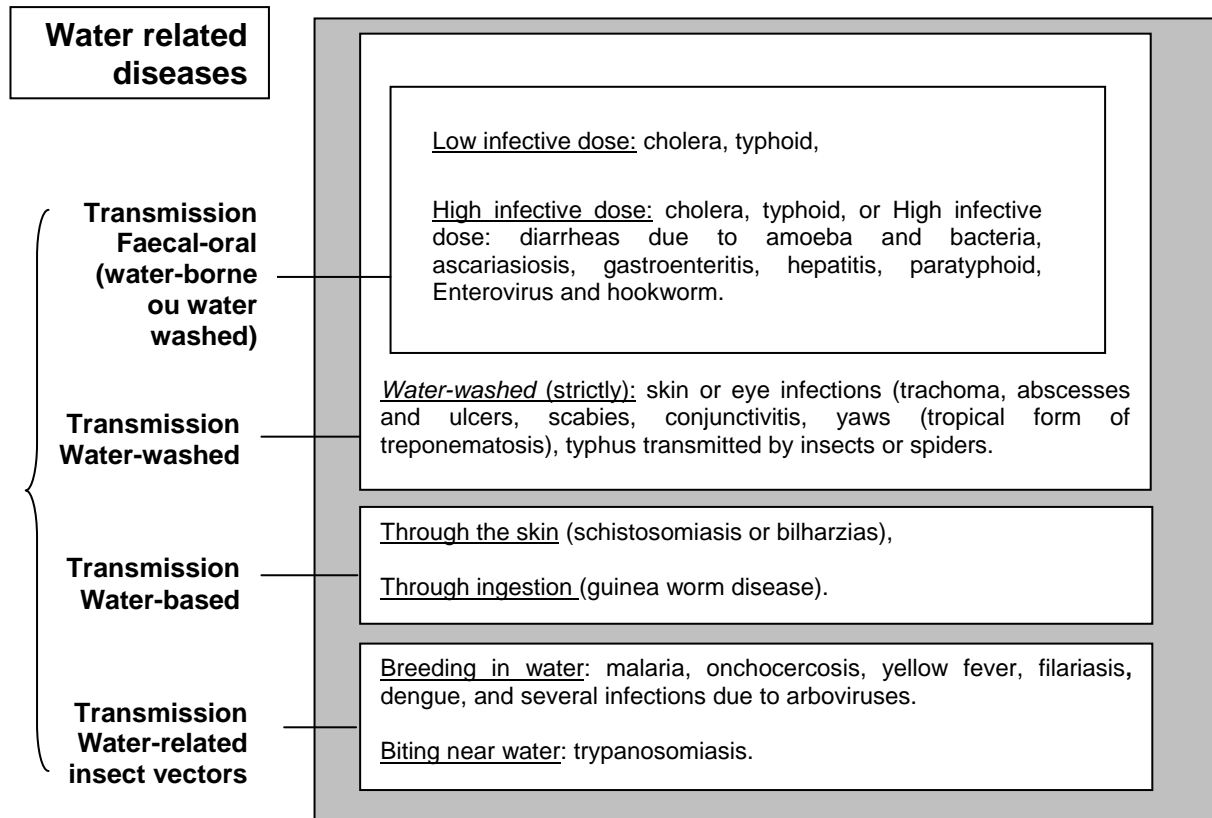| **Water related diseases**	
Transmission Faecal-oral (water-borne ou water washed)	Low infective dose: cholera, typhoid, High infective dose: cholera, typhoid, or High infective dose: diarrheas due to amoeba and bacteria, ascariasiosis, gastroenteritis, hepatitis, paratyphoid, Enterovirus and hookworm.
Transmission Water-washed	*Water-washed* (strictly): skin or eye infections (trachoma, abscesses and ulcers, scabies, conjunctivitis, yaws (tropical form of treponematosis), typhus transmitted by insects or spiders.
Transmission Water-based	Through the skin (schistosomiasis or bilharzias), Through ingestion (guinea worm disease).
Transmission Water-related insect vectors	Breeding in water: malaria, onchocercosis, yellow fever, filariasis**,** dengue, and several infections due to arboviruses. Biting near water: trypanosomiasis.

Fig. n°13   Classification of WASH related diseases based on transmission modes (DOWII)

The main objective of **DOWI and DOWII** interventions consisted in improving the access to drinkable water and to implement a sanitation network to reduce the transmission of infections responsible for diarrheas. The authors reported the following:

- The improvement in water distribution led to reduce the fecal-oral transmitted diseases thanks to the improvement of the quality of water and the "water-washed" transmissions by increased the available quantity.

- The implementation or the improvement of sanitation measures contributed to reduce the transmission of "water related insects vectors".

- Promoting training in personal hygiene reduced the transmission of water-washed diseases and it appeared that it played a preventive part too on the transmission of water-borne infections. Please refer to DOWII – Table 9.1.

- The improvement of latrines and sanitation stopped most of the fecal-oral transmitted infections by limiting them to the contamination of grounds and water by human feces. For example the use of well-ventilated latrines reduced by 50% the incidence of diarrheas in DOWII study – Fig. 9.3).

Infection	Transmission pattern	Preventive measure						
		Human excreta disposal	Solid waste disposal	Waste water disposal	Safe water chain	Hand washing	Food hygiene	Washing clothes and body
Various types of diarrhoea, dysentery, poliomyelitis, typhoid and paratyphoid, hepatitis A	From human faeces to mouth (faecal-oral) via multiple routes of faecal contaminated water, fingers and hands, food, soil and surfaces. Animal faeces may also contain diarrhoeal diseases organisms	X	X		X	X	X	
Roundworm (Ascariasis) Whipworm (Trichuriasis)	From faeces to mouth: worm eggs in human faeces have to reach soil to develop into an infective stage before being ingested through raw food, dirty hands and playing with things that have been in contact with infected soil. Soil on feet and shoes can transport eggs long distances. Animals eating human faeces pass on the eggs in their own faeces	X	X			X	X	
Hookworm	From faeces to skin (especially feet): worm eggs in the faeces have to reach the moist soil, where they hatch into larvae which enter the skin of people's feet	X						
Schistosomiasis (Bilharzia)	From faeces to urine to skin: worm eggs in human faeces or urine have to reach water where they hatch and enter snails. In the snails they develop and are passed on as free swimming 'cercariae' which penetrate the skin when people come into contact with infested waters.	X			X			
Scabies, Ringworm, Yaws	From skin to skin: both through direct skin contact and through sharing clothes, bedclothes and towels							X
Trachoma, conjunctivitis	From eye to eye: both direct contact with the discharge from an infected eye and through contact with articles spoiled by a discharge, such as towels, bedding, clothing, wash basins, washing water. Flies may also act as transmission agents.							X
Louse-borne typhus, Louse-borne relapsing fever	From person to person through the bites of body lice and through sharing clothes and bed clothes, particularly when underwear is not washed regularly							X
Malaria, dengue fever, yellow fever	From person to person through the bite of infested mosquitoes. The mosquito breeds in standing water.			X				
Leishmaniasis	From person to person through the bite of infected sand flies. They breed in damp organic debris, including excreta and solid waste.	X	X					

Fig. n° 14   Transmission patterns and preventive measures for WASH related diseases, adapted from Boot, Cairncross, 1993, MoH Uganda, 1998

Epidemiological arguments supposed that sanitation is as important as the increase in the quantity of available water. We should note here that very often sanitation incurs major changes in behaviors, especially an increase in the households' expenses (cf. the price of water below)

Sanitation is highly efficient to fight against infections due to worms. The authors insisted on the fact that we should not only think of adults, but consider carefully children whose feces are even more important. Children are the first victims of diarrheas and other diseases related to fecal-oral transmission, but they are also the main probable source of infections (Please refer to DOWII p.75).

DOWII (2001) authors have recently published other results concerning the relationships between water, sanitation and infections (Tumwine and al. 2002 and 2003). Please read also the brief presentation of Thompson and al., 2002,

3.1.5 THE PRICE OF WATER

Both studies (**DOW I & II)** evidenced a huge improvement in the access to drinkable water in some regions (Households without piped water doubled their water consumption per inhabitant) and also on the contrary we noted some decline in other areas (the piped systems were over-utilized or out of order). The article of Porras, 2001 studied the cost of water according to the water distribution way ("piped versus un-piped"), the energy necessary to supply water, etc. The cost of water dropped for households having a "piped" connection and, on the contrary, it increased for households having no "piped" connection. Water is more expensive in urban areas for non connected households, i.e. where the dependency towards suppliers is greater. The difference between non connected rural/urban households doubled since 1967 from 0.30 US$ to 0.60 US$ per cubic meter. Please read Moriarty, 2003 too in which the authors assessed the price of water according to the access facilities.

Niveau de service	Handpump	Communal stand post	Yard tank (low pressure)	Roof tank (medium pressure)	Piped water and house connexion (full pressure)
Context	rural	rural/ peri-urban	urban	urban	urban
Typical consumption (l/p/d)	15-25	15-25	25	60	120
Capital cost (Euro/Household/month)	25	305	390	470	530
O and M costs (Euro/Household/month)	0.4	1.4	2	2.4	3.8

<u>Note</u> : O and M costs exclude capital repayment

Fig. n° 15   Incremental costs of providing domestic water supply, Moriarty, P. IRC, 2003

3.2   The Impact of Improvement of Water Supply on Diarrhea

In Eastern Africa diarrhea is the major public health issue which has its origin in water and sanitation problems and can be either *water-borne* or *water-washed*. The quantity of water consumed depends on the easy access to it. As the DOW I et DOWII results put it forward, if there is access to drinkable water from a water point located in the house or in the garden, then water consumption decreases rather sharply when water has to be carried over several minutes from the well to the home. This "plateau effect" is essential since DOWI evidenced that the quantity of water brought to the home is the same whatever the distance may be (30 meters or 1,000 meters). This diagram *en plateau* appears in articles relating to this issue.
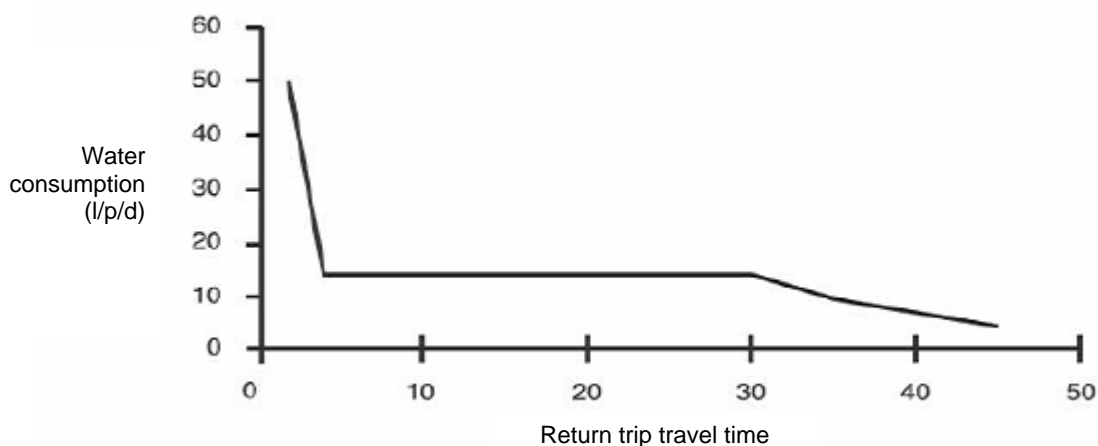

Fig. n° 16   Graph of travel time (in minutes) versus consumption (WELL, 1998)

In a meta-analysis, Esrey, 1991, studied the impact of improving water supply and sanitation on mortality and morbidity of various affections (ascariasis, diarrheic diseases, Guinea worm disease, hookworm disease, schistosomiasis and trachoma). Regarding diarrhea, the reduction in morbidity (incidence and prevalence) was estimated at 25% if we improved the access to drinkable water, at 22% if we improved the disposal of feces and at 16% if we improved the quality of water. But the effects are not cumulating since the improvement is only estimated at 37% if we improved both the access to and the quality of water (whereas theoretically it is at 41%). In 1991 the same authors noted that the impact of the improvement of sanitation facilities was much higher on the severity of the disease than on its incidence or prevalence.

In the article of Howard, 2003 the same data as those of Esrey (1991) are presented and it is worth noticing they are still valid.

In a study covering several countries (Burundi, Ghana, Togo, Uganda, Sri Lanka, Morocco, Bolivia and Guatemala), Esrey (1996) found that the improvement in terms of sanitation is much more positive that the improvement in the quality of the water. In Indonesia, Wibowo et Tisdell (1993) brought additional evidences on the importance of improving the quality of water and sanitation on the morbidity related to transmitted diseases, more particularly diarrheic diseases. But these authors –as Esrey (1996) note that the increase in the available quantity and those of the quality of water are factors much more important to the health than to the control of feces disposal.

In a recent article, Merchant, 2003 analyzed the data of a study carried out in 1988 in areas close to Khartoum and Crezira which aim was to examine the relationships existing between sanitation facilities at families' disposal and the children's growth. This is a prospective survey over 18 months and on 25,483 children aged between 6 to 72 months. The impact on growth was assessed in compliance with stunting risks and the possibility to catch up for that stunting. Four types of families were identified according to their sanitation facilities:
1- Tap water/latrines.
2- Tap water/no latrines.
3- No tap water/latrines.
4- No tap water/no latrines.

	Unadjusted	Ajusted[5]
	RR (95% CI)	RR (95% CI)
Reversal of stunting		
Water and sanitation	2.20 (1.93-2.49)	1.17 (0.99-1.38)
Water, no sanitation	1.21 (1.12-1.32)	1.23 (1.13-1.34)
No water, sanitation	1.32 (1.24-1.41)	1.15 (1.08-1.24)
No water, no sanitation	1.00	1.00
Incidence of stunting		
Water and sanitation	0.50 (0.45-0.55)	0.79 (0.69-0.90)
Water, no sanitation	0.79 (0.73-0.84)	0.79 (0.74-0.85)
No water, sanitation	0.78 (0.74-0.82)	0.86 (0.81-0.91)
No water, no sanitation	1.00	1.00

Fig. n°17 Risk reduction (RR): Water and sanitation associated with improved child growth
Merchant, Jones, Kiure, Kupka, Fitzmaurice, Herrera and Fawzi, 2003

---

[5] Adjusted by age (<1, 1-3, 3+), region, sex, mothers education level, hygiene and breast-feeding status

The chronic malnutrition index (mean height-for-age z-score) was –1.66 and -1.55 for groups 1 & 2 and –2.03 and –1.94 for groups 3 & 4. Several selection factors were introduced: age, geographic area, gender, mothers' literacy level, medical intervention (supplementation in Vitamin A or not vs. placebo), households' income, breast-feeding and cleanliness. Children having a normal weight/age ratio at the beginning of the study, the malnutrition risk (z-score height/age <-2) was at its lowest in group 1 compared with the other groups. Children already suffering from chronic malnutrition at the beginning of the study and belonging to group 1 had 17% chances to better recover than those belonging to group 4 (no tap water/no latrines). The authors did not mention any relationship between access to drinkable water and sanitation.

A similar cohort study on Peruvian children was carried out, but with slightly different results (Checkley 2004). The children living in households with poor sanitation conditions were smaller by one centimeter and they suffered from more diarrheic episodes (54%) than other children. One of the conclusions reached by the authors was to insist on the necessity to improved the quality and the quantity of water available in households in order to avoid water storage in containers that is a source of contamination. These improvements are one way to reduce the incidence of diarrheas and to help children to grow. The same conclusions were found in studies on Pakistan. (Van der Hoek 2002) in a study on the impact of using irrigation water on morbidity of diarrhea and malnutrition: the increase in the quantity of available water and the building of latrines were the most important improvement factors.

3.3 How to Measure the Impact of Water and Sanitation on Health ?

Cairncross and al 2003 issued a detailed criticism on all the studies that measured the impact of the improvement of access to water and sanitation on health. It appears that it is not possible to do such measurements for methodological, ethics and political reasons. He insisted on the fact that all "impact" studies reporting that there exist benefits on health due to the improvement of access to water and sanitation, all presented programs of hygiene improvement (as in Burkina Faso (Curtis, 2001) and on-going programs in Nepal, China, Peru and Senegal (Curtis and al. (2), 2003).

However, in the latest article published (Moraes 2003), the authors mention that the improvement of draining and sewage systems had a positive effect on the incidence of diarrheas. They concluded that the improvement of community sanitation might have an impact on the incidence of infectious diseases without compulsorily promoting hygiene at the same time. Finally it should be stressed here that some experts put into question the relationship between improving the access to water and the decrease in the morbidity due to diarrhea / reduction of malnutrition. The controversy on that debate is still going on (please refer to the works of Briend's team (Poskitt and al. 1999).

3.3.1 THE ROLE OF HYGIENE

Most cases of endemic diarrheas are not due to the transmission of pathogens by water, but they are transmitted from individual to individual because of lack of hygiene (Cairncross and al. 2003). To enhance public health, the access to drinkable water must be accompanied at the same time by sanitation works and hygiene raising awareness among populations. Promoting hygiene is particularly cost-effective: for example washing one's hands with soap can reduce the frequency of diarrhea by 40%, but that implies the supply of water and soap (Cairncross 2003a) (Snel, 2003). Finally the way mothers apprehend the origin of their children's diarrhea must be taken into consideration (Nielsen et al, 2003).

Curtis and Cairncross studied the impact of "washing one's hands" with soap on the risk of diarrheic infections in populations at risk. The meta-analysis (Curtis 2003b) took into consideration the studies carried out until the end of 2002. According to the authors, out of the 38 studies that were analyzed, they all had methodological errors and only 17 could be referred to, although all the articles concluded that "washing one's hands + soap" had a positive effect and the risk of suffering from diarrheic infections decreased by 47%. The authors are debating on the fact that all the articles have the same conclusion but none of those articles use an analytical method producing key results. Regarding the assessment of potential reduction of mortality, it should be of about 17%, i.e. ~1 million children per year.

Answering to about the Kyoto Summit (March 2003), an Indian correspondent (Sudevan Paramoo) underlines that the efficiency of washing one's hands strongly depends on the quality of the water (non contaminating) and the containers used. An Australian correspondent (Alan E Dugdale) recalls that, for Muslims, the right hand is intended to do clean things (eating, welcoming, etc.). He suggests that this practice be carefully applied, all the more so that Western influence weakened such hygiene attitudes.
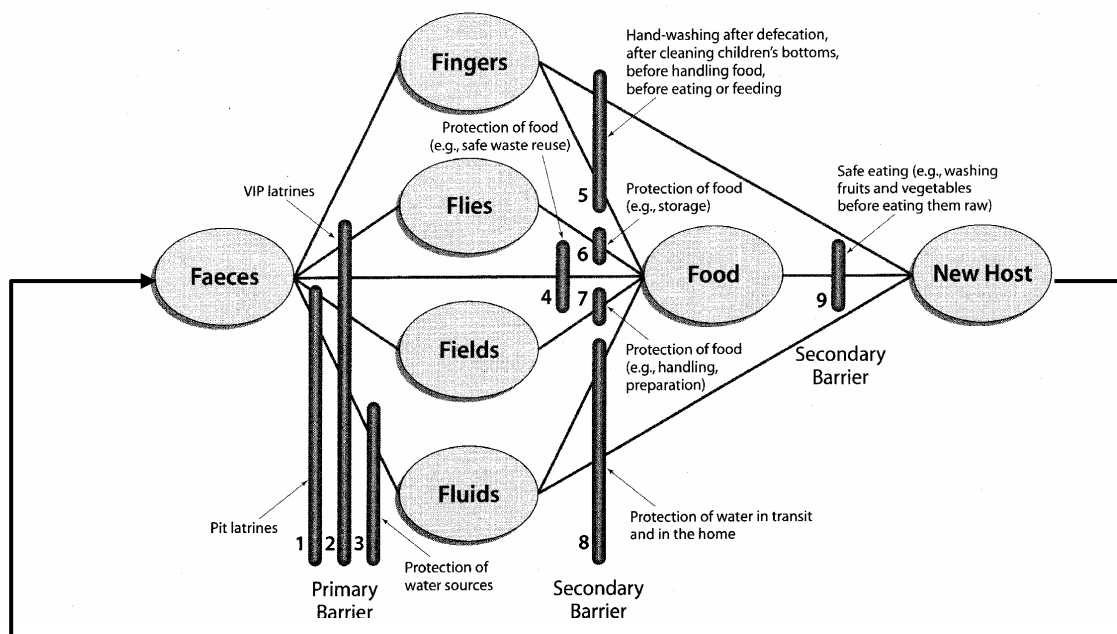

Fig. n°18 Faecal-oral routes of disease transmission (Source: LSHTM – UNICEF – ODA - INFDC)

3.3.2 INDIRECT INFLUENCE OF SANITATION

Water is not only used for drinking and washing our hands, but it helps increasing farming productivity, small equipment (grinding mills, mixers, etc.), local industries, etc. Please read the report written by Moriarty and al, 2003, and the article of Linden, 2001 as well as an extensive bibliography on rainwater storage (Smet, 2003).

3.4 How Can the Domestic Quality of Water Be Improved?

In this paragraph we mean improving access to drinkable water for domestic purposes, i.e. starting from the home. Many means have already been suggested so far to purify drinkable water and water used for cooking meals: here are just indicative examples.

- **Boiling water**, but it is costly in terms of time and energy (using wood and the deforestation risk, etc.)

- **Chlorination** consists in adding chlorine to water of poor quality in view of making it drinkable for human beings. It is an emergency practice, but it is not fully reliable since water cannot be purified at 100%. More particularly some micro-particles of faeces are not fully destructed and it is necessary to proceed with micro-filtration (Schoenen, 2002). A study in Pakistan led by Cairncross and his colleagues (Jensen, 2002) evidenced that the reduction of fecal bacteria further to the chlorination of drinking water (supplemented with chlorine directly within the circuit of public water distribution) has no effect on the incidence of diarrheas. Nevertheless, a comparative study by Sobsey (2003) on the number of diarrheic episodes in the "intervention" households (1-5-mgL of hypochlorite into the containers of water stored for the family use) and the 'control' households. The results evidenced prevention in the number of diarrheic episodes of 43% in Bolivia and 24%. Many information can be found on this technique in Brown J. , 2003 pages 12-13 thesis.

- **Filtration**: Microbes and other colloidal particles can be removed from water through physical processes. The size of pathogens is the main factor to take into account before using such process. Thus viruses measuring 20-100 nano-meters can hardly ever be eliminated; bacteria most of them measuring 0.5 to 3 micrometers will disappear more easily as well as protozoa and multicellular animals (3-30 micrometers). There are many processes (please also refer to Brown's Thesis (2003) concerning ceramic filters. A comparative study on the main techniques of purifying water can be displayed from the Website www.safewatersystems.com. This study compares efficiency, easy performance and maintenance (needs for qualified or non-qualified staff), quantity of energy necessary to operate the system, the impact on water taste, etc.

- **Shape of containers used to store water**: for instance, manufacture containers with narrow necks which avoid any contact between the user and the stored water (Jensen, 2002).
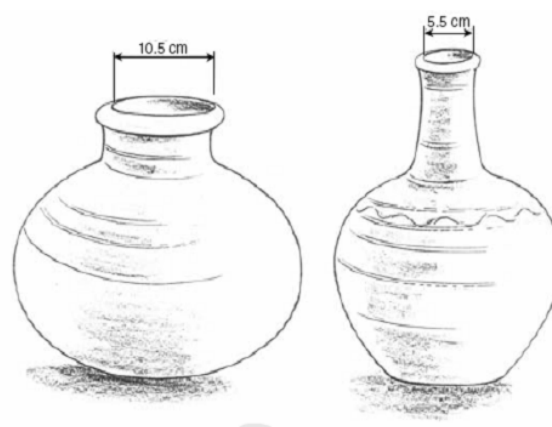

Fig. n°19   Example of the water contamination risk for during its domestic storage (according to JENSEN 2002)

- **Solar disinfection of water**: One simple and efficient way to increase the positive impact of "washing one's hands+soap" consists in the solar disinfection of water (SODIS). In its most elementary technique, it consists in filling transparent plastic bottles with water and to expose them to the direct light of the sun for at least 6 hours. The synergy between solar radiation (UV-A) and the rise the temperature (> 45°C) inactivates most of enteropathogens that are contained in water. This inactivation process was characterized by McGuigan (1998 & 1999). A study carried out in Kenya (Conroy, 1999 and 2001) shows a sustainable reduction of about 16% in severe diarrhea risks. Another study (Gericke, 2003) reports results obtained in Kenya: **SODIS** enabled to reduce the risks of diarrheas and cholera in young children. Lastly, the website http://(www.sodis.ch) provides a list of all countries where this disinfection technique of water has been used so far (Colombia, Bolivia, Burkina Faso, Togo, Indonesia, Thailand and China).

Thermoresistance of micro organisms			
Micro organism	Time and Temperature for 100% destruction		
	1 Min	**6 Min**	**60 Min**
Enteroviruses	-	-	62°C
Rotaviruses	63°C for 30 Min		
Faecal coliforms (E. coli)	80°C	-	-
Salmonellae	-	62°C	58°C
Shigella	-	61°C	54°C
Vibrio Cholerae	-	-	45°C
Entamoeba, Histolytica cysts	57°C	54°C	50°C
Giardia cysts	57°C	54°C	50°C
Hookworm eggs and larvae	-	62°C	51°C
Ascaris eggs	68°C	62°C	57°C
Schistosomas eggs	60°C	55°C	50°C
Taenia eggs	65°C	57°C	51°C

Fig. n°20   Thermoresistance of micro organisms (from the Website SODIS)

INDICATIVE BIBLIOGRAPHY

54th WHA. Infant and young child nutrition, Agenda item 13.1. Fifty fourth World Health Assembly 54.2 18 May 2001. 2001.

Ahmed, M., Billoo, A.G., and Murtaza, G. (1995). Risk factors of persistent diarrhoea in children below five years of age. J.Pak.Med.Assoc. *45*, 290-292.

Alam, M., Akhtar,Y.N., Ali,S.S., Ahmed,M., Atiq,M., Ansari,A., Chaudhry,F.A., Bashir,H., Bangash,M.A., Awais,A., Safdar,A., Hasnain,S.F., and Zafar,A. (2003). Seasonal variation in bacterial pathogens isolated from stool samples in Karachi, Pakistan. J.Pak.Med.Assoc. *53*, 125-129.

Almeida, S.S., Duntas,L.H., Dye,L., Nunes,M.L., Prasad,C., Rocha,J.B., Wainwright,P., Zaia,C.T., and Guedes,R.C. (2002). Nutrition and brain function: a multidisciplinary virtual symposium. Nutr.Neurosci. *5*, 311-320.

Anderson, E.J. and Weber,S.G. (2004). Rotavirus infection in adults. Lancet Infect.Dis. *4*, 91-99.

Appleton. Hygiene promotion. Thematic overview IRC International water and sanitation Centre. 1-60. 2003.

ASCON 10th. ASCON 10th Annual Scientific Conference . MALNUTRITION: MEETING THE CHALLENGES IN SOUTH ASIA. 2002. 6-11-0002.

Ashworth, A. (2001). Treatment of severe malnutrition. J.Pediatr.Gastroenterol.Nutr. *32*, 516-518.

Audu,R., Omilabu,S.A., Peenze,I., and Steele,D. (2002). Viral diarrhoea in young children in two districts in Nigeria. Cent.Afr.J.Med. *48*, 59-63.

Bagott,M. (1999). Need to consider other causes of poor growth in Gambian children. Arch.Dis.Child *81*, 279.

Baltazar,J.C., Nadera,D.P., and Victora,C.G. (2002). Evaluation of the national control of diarrhoeal disease programme in the Philippines, 1980-93. Bull.World Health Organ *80*, 637-643.

Bartram,J. (2003). New water forum will repeat old message. Bull.World Health Organ *81*, 158.

Beinner,M.A. and Lamounier,J.A. (2003). Recent experience with fortification of foods and beverages with iron for the control of iron-deficiency anemia in Brazilian children. Food Nutr.Bull. *24*, 268-274.

Beisel,W.R. (2003). Symposium introduction. Nutrition and Infection, Prologue and Progress since 1968 (2002 Experimental Biology Meeting. NewOrleans,LA). J.Nutr. *133*, 314S-315S.

Bhandari,N., Bahl,R., Taneja,S., Strand,T., Molbak,K., Ulvik,R.J., Sommerfelt,H., and Bhan,M.K. (2002). Substantial reduction in severe diarrheal morbidity by daily zinc supplementation in young north Indian children. Pediatrics *109*, e86.

Bhandari,N., Bahl,R., Mazumdar,S., Martines,J., Black,R.E., and Bhan,M.K. (2003). Effect of community-based promotion of exclusive breastfeeding on diarrhoeal illness and growth: a cluster randomised controlled trial. Lancet *361*, 1418-1423.

Bhaskaram,P. (2002). Micronutrient malnutrition, infection, and immunity: an overview. Nutr.Rev. *60*, S40-S45.

Bhutta,Z.A., Black,R.E., Brown,K.H., Gardner,J.M., Gore,S., Hidayat,A., Khatun,F., Martorell,R., Ninh,N.X., Penny,M.E., Rosado,J.L., Roy,S.K., Ruel,M., Sazawal,S., and Shankar,A. (1999). Prevention of diarrhea and pneumonia by zinc supplementation in children in developing countries: pooled analysis of randomized controlled trials. Zinc Investigators' Collaborative Group. J.Pediatr. *135*, 689-697.

Bhutta,Z.A., Bird,S.M., Black,R.E., Brown,K.H., Gardner,J.M., Hidayat,A., Khatun,F., Martorell,R., Ninh,N.X., Penny,M.E., Rosado,J.L., Roy,S.K., Ruel,M., Sazawal,S., and Shankar,A. (2000). Therapeutic effects of oral zinc in acute and persistent diarrhea in children in developing countries: pooled analysis of randomized controlled trials. Am.J.Clin.Nutr. *72*, 1516-1522.

Bittencourt,J.A., Arbo,E., Malysz,A.S., Oravec,R., and Dias,C. (2000). Seasonal and age distribution of rotavirus infection in Porto Alegre--Brazil. Braz.J.Infect.Dis. *4*, 279-283.

Black,R.E., Brown,K.H., and Becker,S. (1984). Malnutrition is a determining factor in diarrheal duration, but not incidence, among young children in a longitudinal study in rural Bangladesh. Am.J.Clin.Nutr. *39*, 87-94.

Black,R.E. (1998). Therapeutic and preventive effects of zinc on serious childhood infectious diseases in developing countries. Am.J.Clin.Nutr. *68*, 476S-479S.

Black,R.E. (2001). Micronutrients in pregnancy. Br.J.Nutr. *85 Suppl 2:S193-7.*, S193-S197.

Black,R.E. and Victora,C.G. (2002). Optimal duration of exclusive breast feeding in low income countries. BMJ *325*, 1252-1253.

Black,R.E. (2003a). Zinc deficiency, infectious disease and mortality in the developing world. J.Nutr. *133*, 1485S-1489S.

Black,R.E., Morris,S.S., and Bryce,J. (2003b). Where and why are 10 million children dying every year? Lancet *361*, 2226-2234.

Blum,D. and Feachem,R.G. (1983). Measuring the impact of water supply and sanitation investments on diarrhoeal diseases: problems of methodology. Int.J.Epidemiol. *12*, 357-365.

Borghi,J., Guinness,L., Ouedraogo,J., and Curtis,V. (2002). Is hygiene promotion cost-effective? A case study in Burkina Faso. Trop.Med.Int.Health *7*, 960-969.

Bradbury,J. (2003). Beyond the Fire-Hazard Mentality of Medicine: The Ecology of Infectious Diseases. PLOS Biology *1*, 148-151.

Briend,A., Hasan,K.Z., Aziz,K.M., and Hoque,B.A. (1989). Are diarrhoea control programmes likely to reduce childhood malnutrition? Observations from rural Bangladesh. Lancet *2*, 319-322.

Briend,A. (1990). Is diarrhoea a major cause of malnutrition among the under-fives in developing countries? A review of available evidence. Eur.J.Clin.Nutr. *44*, 611-628.

Brown,J. Evaluation of point-of-use microfiltration for drinking water treatment in rural Bolivia. 1-89. 2003. University of Cambridge.

Brown,K.H., Stallings,R.Y., de Kanashiro,H.C., Lopez,d.R., and Black,R.E. (1990). Effects of common illnesses on infants' energy intakes from breast milk and other foods during longitudinal community-based studies in Huascar (Lima), Peru. Am.J.Clin.Nutr. *52*, 1005-1013.

Brown,K.H., Golden,B., Fuchs,G., and Swapan,R. Zinc deficiency. 17-22. 2001.

Brown,K.H. (2003). Diarrhea and malnutrition. J.Nutr. *133*, 328S-332S.

Bryce,J., el Arifeen,S., Pariyo,G., Lanata,C., Gwatkin,D., and Habicht,J.P. (2003). Reducing child mortality: can public health deliver? Lancet *362*, 159-164.

Cairncross,S. Why promote sanitation? 2003

Cairncross,S. Measuring the health impact of water and sanitation. 1-4. 2003

Cairncross,S., O`Neill,D., McCoy,A., and Sethi,D. Health, environment and the burden of Disease; a guidance note. 1-53. 2003c. DFID.

Cardoso,D.D., Soares,C.M., Dias e Souza MB, de Azevedo,M.S., Martins,R.M., Queiroz,D.A., de Brito,W.M., Munford,V., and Racz,M.L. (2003). Epidemiological features of rotavirus infection in Goiania, Goias, Brazil, from 1986 to 2000. Mem.Inst.Oswaldo Cruz *98*, 25-29.

Castillo-Duran,C., Vial,P., and Uauy,R. (1988). Trace mineral balance during acute diarrhea in infants. J.Pediatr. *113*, 452-457.

Ceesay,S.M., Prentice,A.M., Cole,T.J., Foord,F., Weaver,L.T., Poskitt,E.M., and Whitehead,R.G. (1997). Effects on birth weight and perinatal mortality of maternal dietary supplements in rural Gambia: 5 year randomised controlled trial. BMJ *315*, 786-790.

Chakravarty,I. and Ghosh,K. (2000). Micronutrient malnutrition--present status and future remedies. J.Indian Med.Assoc. *98*, 539-542.

Checkley,W., Gilman,R.H., Black,R.E., Lescano,A.G., Cabrera,L., Taylor,D.N., and Moulton,L.H. (2002). Effects of nutritional status on diarrhea in Peruvian children. J.Pediatr. *140*, 210-218.

Checkley,W., Gilman,R.H., Black,R.E., Epstein,L.D., Cabrera,L., Sterling,C.R., and Moulton,L.H. (2004). Effect of water and sanitation on childhood health in a poor Peruvian peri-urban community. Lancet *363*, 112-118.

Conroy,R.M., Meegan,M.E., Joyce,T., McGuigan,K., and Barnes,J. (1999). Solar disinfection of water reduces diarrhoeal disease: an update. Arch.Dis.Child *81*, 337-338.

Corvalan,C.F., Kjellstrom,T., and Smith,K.R. (1999). Health, environment and sustainable development: identifying links and indicators to promote action. Epidemiology *10*, 656-660.

Cousens,S., Nacro,B., Curtis,V., Kanki,B., Tall,F., Traore,E., Diallo,I., and Mertens,T. (1993). Prolonged breast-feeding: no association with increased risk of clinical malnutrition in young children in Burkina Faso. Bull.World Health Organ *71*, 713-722.

Curtis,V., Cousens,S., Mertens,T., Traore,E., Kanki,B., and Diallo,I. (1993). Structured observations of hygiene behaviours in Burkina Faso: validity, variability, and utility. Bull.World Health Organ *71*, 23-32.

Curtis,V. and Kanki,B. (1998). Hygiene promotion in Burkina Faso. Afr.Health 20, 9, 11-9, 12.

Curtis,V., Cairncross,S., and Yonli,R. (2000). Domestic hygiene and diarrhoea - pinpointing the problem. Trop.Med.Int.Health 5, 22-32.

Curtis,V., Kanki,B., Cousens,S., Diallo,I., Kpozehouen,A., Sangare,M., and Nikiema,M. (2001a). Evidence of behaviour change following a hygiene promotion programme in Burkina Faso. Bull.World Health Organ 79, 518-527.

Curtis,V. (2001b). Hygiene: how myths, monsters, and mothers-in-law can promote behaviour change. J.Infect. 43, 75-79.

Curtis,V. and Biran,A. (2001). Dirt, disgust, and disease. Is hygiene in our genes? Perspect.Biol.Med. 44, 17-31.

Curtis,V. and Cairncross,S. (2003a). Effect of washing hands with soap on diarrhoea risk in the community: a systematic review. Lancet Infect.Dis. 3, 275-281.

Curtis,V. (2003b). Talking dirty: how to save a million lives. Int.J.Environ.Health Res. 13 Suppl 1:S73-9., S73-S79.

Curtis,V. and Cairncross,S. (2003c). Water, sanitation, and hygiene at Kyoto. BMJ 327, 3-4.

de Jong,D., Dietvorst,C., Markowski,V., and Pels,J. FLOOD OF GATEWAYS AND PORTALS ON WATER DROWNING IN AMBITION IRC International Water and Sanitation Centre. 1-15. 2003.

Delange,F; Lecomte,P. (2000). Iodine supplementation: benefits outweigh risks. Drug Saf 22, 89-95.

Delange,F. (2000). The role of iodine in brain development. Proc.Nutr.Soc. 59, 75-79.

Delange,F. (2001). Iodine deficiency as a cause of brain damage. Postgrad.Med.J. 77, 217-220.

Delaunay,V., Etard,J.F., Preziosi,M.P., Marra,A., and Simondon,F. (2001). Decline of infant and child mortality rates in rural Senegal over a 37-year period (1963-1999). Int.J.Epidemiol. 30, 1286-1293.

Diarrhées infectieuses: comment fonctionne la barrière intestinale. trouvé sur le web . 2003.

Elvevoll,E.O. and James,D. (2001). The emerging importance of dietary lipids, quantity and quality, in the global disease burden: the potential of aquatic resources. Nutr.Health 15, 155-167.

e-Medecine.com. Gastroenteritis excerpt. eMedecine.com . 2004.

Emerging WHO. Emerging issues in water and infectious disease. 1-24. 2003.

Erickson,K.L., Medina,E.A., and Hubbard,N.E. (2000). Micronutrients and innate immunity. J.Infect.Dis. 182 Suppl 1:S5-10., S5-10.

Esrey,S.A., Feachem,R.G., and Hughes,J.M. (1985). Interventions for the control of diarrhoeal diseases among young children: improving water supplies and excreta disposal facilities. Bull.World Health Organ 63, 757-772.

Esrey,S.A., Potash,J.B., Roberts,L., and Shiff,C. (1991). Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. Bull.World Health Organ *69*, 609-621.

Esrey,S.A. (1996). Water, waste, and well-being: a multicountry study. Am.J.Epidemiol. *143*, 608-623.

Ezzati,M., Lopez,A.D., Rodgers,A., Vander,H.S., and Murray,C.J. (2002). Selected major risk factors and global and regional burden of disease. Lancet *360*, 1347-1360.

Faulkner,C.T., Garcia,B.B., Logan,M.H., New,J.C., and Patton,S. (2003). Prevalence of endoparasitic infection in children and its relation with cholera prevention efforts in Mexico. Rev.Panam.Salud Publica *14*, 31-41.

Feinle-Bisset,C., Vozzo,R., Horowitz,M., and Talley,N.J. (2004). Diet, food intake, and disturbed physiology in the pathogenesis of symptoms in functional dyspepsia. Am.J.Gastroenterol. *99*, 170-181.

Francois,D., Burgi,H., Chen,Z.P., and Dunn,J.T. (2002). World status of monitoring iodine deficiency disorders control programs. Thyroid *12*, 915-924.

Gasana,J., Morin,J., Ndikuyeze,A., and Kamoso,P. (2002). Impact of water supply and sanitation on diarrheal morbidity among young children in the socioeconomic and cultural context of Rwanda (Africa). Environ.Res. *90*, 76-88.

Geerligs,P.D., Brabin,B.J., and Omari,A.A. (2003). Food prepared in iron cooking pots as an intervention for reducing iron deficiency anaemia in developing countries: a systematic review. J.Hum.Nutr.Diet. *16* , 275-281.

Gendrel,D., Treluyer,J.M., and Richard-Lenoble,D. (2003). Parasitic diarrhea in normal and malnourished children. Fundam.Clin.Pharmacol. *17*, 189-197.

Gericke,C.A. An integrated strategy to reduce diarrhoea-related burden of disease in highly constrained settings. BMJ . 2003.

Gillespie,D., Claeson,M., Mshinda,H., and Troedsson,H. (2003). Knowledge into action for child survival. Lancet *362*, 323-327.

Glass,R.I., Bresee,J., Jiang,B., Gentsch,J., Ando,T., Fankhauser,R., Noel,J., Parashar,U., Rosen,B., and Monroe,S.S. (2001). Gastroenteritis viruses: an overview. Novartis.Found.Symp. *238:5-19; discussion;%19-25.*, 5-19.

Glinoer,D. (2003). Feto-maternal repercussions of iodine deficiency during pregnancy. An update. Ann.Endocrinol.(Paris) *64*, 37-44.

Golden,M.H. (1995). Specific deficiencies versus growth failure: type I and type II nutrients. SCN News 10-14.

Goodgame,R.W. (2001). Viral causes of diarrhea. Gastroenterol.Clin.North Am. *30*, 779-795.

Gorter,A.C., Sandiford,P., Smith,G.D., and Pauw,J.P. (1991). Water supply, sanitation and diarrhoeal disease in Nicaragua: results from a case-control study. Int.J.Epidemiol. *20,* 527-533.

Gracey,M. (1999). Nutritional effects and management of diarrhoea in infancy. Acta Paediatr.Suppl *88*, 110-126.

Grantham-McGregor,S.M., Walker,S.P., and Chang,S. (2000). Nutritional deficiencies and later behavioural development. Proc.Nutr.Soc. *59*, 47-54.

Grotto,I., Mimouni,M., Gdalevich,M., and Mimouni,D. (2003). Vitamin A supplementation and childhood morbidity from diarrhea and respiratory infections: a meta-analysis. J.Pediatr. *142*, 297-304.

Guay,L.A. and Ruff,A.J. (2001). HIV and infant feeding: an ongoing challenge. JAMA *286*, 2462-2464.

Guerrant,R.L., Schorling,J.B., McAuliffe,J.F., and de Souza,M.A. (1992). Diarrhea as a cause and an effect of malnutrition: diarrhea prevents catch-up growth and malnutrition increases diarrhea frequency and duration. Am.J.Trop.Med.Hyg. *47*, 28-35.

Guerrant,R.L., Kosek,M., Moore,S., Lorntz,B., Brantley,R., and Lima,A.A. (2002). Magnitude and impact of diarrheal diseases. Arch.Med.Res. *33*, 351-355.

Handbook of Nut... (2004). Handbook of Nutrition and Immunity.

Hasan,K.Z., Briend,A., Aziz,K.M., Hoque,B.A., Patwary,M.Y., and Huttly,S.R. (1989). Lack of impact of a water and sanitation intervention on the nutritional status of children in rural Bangladesh. Eur.J.Clin.Nutr. *43*, 837-843.

Hautvast,J.L., van der Heijden,L.J., Luneta,A.K., van Staveren,W.A., Tolboom,J.J., and van Gastel,S.M. (1999). Food consumption of young stunted and non-stunted children in rural Zambia. Eur.J.Clin.Nutr. *53*, 50-59.

Heller,L., Colosimo,E.A., and Antunes,C.M. (2003). Environmental sanitation conditions and health impact: a case-control study. Rev.Soc.Bras.Med.Trop. *36*, 41-50.

Hoddinott,J. Water, Health, and Income: a Review. Discussion paper Nb 25, 1-35. 1997. Food Consumption and Nutrition Division.

Hoddinott,J. and Yohannes,Y. Dietary Diversity as a Food Security Indicator. Food and Nutrition Technical Assistance Project, Academy for Educational Development, Washington, D.C. Dietary Diversity as a Food Security Indicator.

Food and Nutrition Technical Assistance Project, Academy for Educational Development, Washington, D.C. 2002. John Hoddinott Yisehac Yohannes, Food and Nutrition Technical Assistance Project (FANTA).

Hoerr,R.A. Book Review: Nutrition and Immunology: Principles and Practice. Am.J.Clin.Nutr. 73[6], 1114-1115. 2001.

Hoque,B.A. (2003). Handwashing practices and challenges in Bangladesh. Int.J.Environ.Health Res. *13 Suppl 1:S81-7.*, S81-S87.

Howard,G. and Bartram,J. Domestic Water Quantity, Service, Level and Health Water sanitation and health. 1-33. 2003.

IFPRI. OVERCOMING WATER SCARCITY AND QUALITY CONSTRAINTS. EDITED BY RUTH S.MEINZEN-DICK AND MARK W.ROSEGRANT. 1-29. 2001.

Inocencio,A., Sally,A., and Merrey,D.J. Innovative Approaches to Agricultural Water Security in Sub-Saharan Africa (Working Paper 55). International Water Management Institute. 2003.

Jensen,P.K., Ensink,J.H., Jayasinghe,G., van der,H.W., Cairncross,S., and Dalsgaard,A. (2002). Domestic transmission routes of pathogens: the problem of in-house contamination of drinking water during storage in developing countries. Trop.Med.Int.Health *7*, 604-609.

Jensen,P.K., Ensink,J.H., Jayasinghe,G., van der,H.W., Cairncross,S., and Dalsgaard,A. (2003). Effect of chlorination of drinking-water on water quality and childhood diarrhoea in a village in Pakistan. J.Health Popul.Nutr. *21*, 26-31.

Juery,C. EAUDOC: YOUR INTERNATIONAL MEMORY FOR WATER" IRC International Water and Sanitation Centre. 1-9. 2003.

Kaferstein, F. (2003). Foodborne diseases in developing countries: aetiology, epidemiology and strategies for prevention. Int.J.Environ.Health Res. *13 Suppl 1:S161-8.*, S161-S168.

Kapikian,A.Z. (2000). The discovery of the 27-nm Norwalk virus: an historic perspective. J.Infect.Dis. *181 Suppl 2:S295-302.*, S295-S302.

Kapil,U. and Bhavna,A. (2002). Adverse effects of poor micronutrient status during childhood and adolescence. Nutr.Rev. *60*, S84-S90.

Kastin,D.A. and Buchman,A.L. (2002). Malnutrition and gastrointestinal disease. Curr.Opin.Clin.Nutr.Metab Care *5*, 699-706.

Kaur,A., Chowdhury,S., and Kumar,R. (1994). Mothers' beliefs and practices regarding prevention and management of diarrheal diseases. Indian Pediatr. *31*, 55-57.

Kent,G. (2002). comments to Mbori-Ngacha et al JAMA 2001, ID207. JAMA *287*, 1110-1114.

Keusch,G.T. (2003). The history of nutrition: malnutrition, infection and immunity. J.Nutr. *133*, 336S-340S.

Kolsteren,P.W., Kusin,J.A., and Kardjati,S. (1997). Morbidity and growth performance of infants in Madura, Indonesia. Ann.Trop.Paediatr. *17*, 201-208.

Koopmans,M., von Bonsdorff,C.H., Vinje,J., de Medici,D., and Monroe,S. (2002). Foodborne viruses. FEMS Microbiol.Rev. *26*, 187-205.

Kosek,M., Bern,C., and Guerrant,R.L. (2003). The global burden of diarrhoeal disease, as estimated from studies published between 1992 and 2000. Bull.World Health Organ *81*, 197-204.

Kossmann,J., Nestel,P., Herrera,M.G., El Amin,A., and Fawzi,W.W. (2000). Undernutrition in relation to childhood infections: a prospective study in the Sudan. Eur.J.Clin.Nutr. *54*, 463-472.

Kossmann,J., Nestel,P., Herrera,M.G., El Amin,A., and Fawzi,W.W. (2000). Undernutrition and childhood infections: a prospective study of childhood infections in relation to growth in the Sudan. Acta Paediatr. *89*, 1122-1128.

Kourtis,A.P., Butera,S., Ibegbu,C., Beled,L., and Duerr,A. (2003). Breast milk and HIV-1: vector of transmission or vehicle of protection? Lancet Infect.Dis. *3*, 786-793.

Kramer MS and Kakuma R. Optimal duration of exclusive breastfeeding (CochraneReview). This review should be cited as: Kramer MS, Kakuma R. Optimal duration of exclusive breastfeeding CochraneReview In The Cochrane Library Issue 1 2004. Chichester UK John Wiley & Sons Ltd. 2002.

Kukuruzovic,R.H. and Brewster,D.R. (2002). Milk formulas in acute gastroenteritis and malnutrition: a randomized trial. J.Paediatr.Child Health *38*, 571-577.

Lanata,C.F. (2003). Studies of food hygiene and diarrhoeal disease. Int.J.Environ.Health Res. *13 Suppl 1:S175-83.*, S175-S183.

Larsen,B. (2003). Hygiene and health in developing countries: defining priorities through cost - benefit assessments. Int.J.Environ.Health Res. *13 Suppl 1:S37-46.*, S37-S46. Ref ID: 172
Reprint: Not in File

Leclerc,H., Mossel,D.A., Edberg,S.C., and Struijk,C.B. (2001). Advances in the bacteriology of the coliform group: their suitability as markers of microbial water safety. Annu.Rev.Microbiol. *55:201-34.*, 201-234.

Leclerc,H., Schwartzbrod,L., and Dei-Cas,E. (2002). Microbial agents associated with waterborne diseases. Crit Rev.Microbiol. *28*, 371-409.

Levine,J.A., Weisell,R., Chevassus,S., Martinez,C.D., Burlingame,B., and Coward,W.A. (2001). The work burden of women. Science *294*, 812.

Logan,S., Martins,S., and Gilbert,R. (2001). Iron therapy for improving psychomotor development and cognitive function in children under the age of three with iron deficiency anaemia. Cochrane.Database.Syst.Rev. CD001444.

Lunn,P.G. (2000). The impact of infection and nutrition on gut function and growth in childhood. Proc.Nutr.Soc. *59*, 147-154.

Luong,T.V. (2003). De-worming school children and hygiene intervention. Int.J.Environ.Health Res. *13 Suppl 1:S153-9.*, S153-S159.

Majumdar,I., Paul,P., Talib,V.H., and Ranga,S. (2003). The effect of iron therapy on the growth of iron-replete and iron-deplete children. J.Trop.Pediatr. *49*, 84-88.

Makins,R. and Ballinger,A. (2003). Gastrointestinal side effects of drugs. Expert.Opin.Drug Saf *2*, 421-429.

Martorell,R., Yarbrough,C., Yarbrough,S., and Klein,R.E. (1980). The impact of ordinary illnesses on the dietary intakes of malnourished children. Am.J.Clin.Nutr. *33*, 345-350.

Mata,L. (1992). Diarrheal disease as a cause of malnutrition. Am.J.Trop.Med.Hyg. *47*, 16-27.

Mnbori-Ngacha,D., Nduati,R., John,G., Reilly,M., Richardson,B., Mwatha,A., Ndinya-Achola,J., Bwayo,J., and Kreiss,J. (2001). Morbidity and mortality in breastfed and formula-fed infants of HIV-1-infected women: A randomized clinical trial. JAMA *286*, 2413-2420.

McGuigan,K.G., Joyce,T.M., Conroy,R.M., Gillespie,J.B., and Elmore-Meegan,M. (1998). Solar disinfection of drinking water contained in transparent plastic bottles: characterizing the bacterial inactivation process. J.Appl.Microbiol. *84*, 1138-1148.

McGuigan,K.G., Joyce,T.M., and Conroy,R.M. (1999). Solar disinfection: use of sunlight to decontaminate drinking water in developing countries. J.Med.Microbiol. *48*, 785-787.

Meier,R., Burri,E., and Steuerwald,M. (2003). The role of nutrition in diarrhoea syndromes. Curr.Opin.Clin.Nutr.Metab Care *6*, 563-567.

Mensah,P. and Tomkins,A. (2003). Household-level technologies to improve the availability and preparation of adequate and safe complementary foods. Food Nutr.Bull. *24*, 104-125.

Merchant,A.T., Jones,C., Kiure,A., Kupka,R., Fitzmaurice,G., Herrera,M.G., and Fawzi,W.W. (2003). Water and sanitation associated with improved child growth. Eur.J.Clin.Nutr. *57*, 1562-1568.

Miah,H. Roles of women in water and sanitation practises. 93. 2002.

Moore,S.E., Cole,T.J., Poskitt,E.M., Sonko,B.J., Whitehead,R.G., McGregor,I.A., and Prentice,A.M. (1997). Season of birth predicts mortality in rural Gambia. Nature *388*, 434.

Moore,S.E., Collinson,A.C., and Prentice,A.M. (2001). Immune function in rural Gambian children is not related to season of birth, birth size, or maternal supplementation status. Am.J.Clin.Nutr. *74*, 840-847.

Moraes,L.R., Cancio,J.A., Cairncross,S., and Huttly,S. (2003). Impact of drainage and sewerage on diarrhoea in poor urban areas in Salvador, Brazil. Trans.R.Soc.Trop.Med.Hyg. *97*, 153-158.

Moriarty,P. The productive use of domestic water supplies IRC International Water and Sanitation Centre. 1-60. 2003.

Murray,C.J., Rodgers,A., Vaughan,P., and Prentice,T. Rapport sur la santé dans le Monde, Réduire les risques et promouvoir une vie saine. WHO , 1-184. 2002.

Nanan,D., White,F., Azam,I., Afsar,H., and Hozhabri,S. (2003). Evaluation of a water, sanitation, and hygiene education intervention on diarrhoea in northern Pakistan. Bull.World Health Organ *81*, 160-165.

Nielsen,M., Hoogvorst,A., Konradsen,F., Mudasser,M., and van der,H.W. (2003). Causes of childhood diarrhea as perceived by mothers in the Punjab, Pakistan. Southeast Asian J.Trop.Med.Public Health *34*, 343-351.

Nunez,F.A., Lopez,J.L., de la Cruz,A.M., and Finlay,C.M. (2003). [Risk factors for Giardia lamblia infection in children in daycare centers in Havana, Cuba]. Cad.Saude Publica *19*, 677-682.

Nutrition and Immunology: Principles and Practice(.1999) (Totowa, NJ.: Humana Press).

Osendarp,S.J., West,C.E., and Black,R.E. (2003). The need for maternal zinc supplementation in developing countries: an unresolved issue. J.Nutr. *133*, 817S-827S.

Parashar,U.D., Hummelman,E.G., Bresee,J.S., Miller,M.A., and Glass,R.I. (2003). Global illness and deaths caused by rotavirus disease in children. Emerg.Infect.Dis. *9*, 565-572.

Parashar,U.D., Bresee,J.S., and Glass,R.I. (2003). The global burden of diarrhoeal disease in children. Bull.World Health Organ *81*, 236.

Parry-Jones S. Some global statisitics for water and sanitiation related disease. 1-3. 2003.

Patel,A.B., Dhande,L.A., and Rawat,M.S. (2003). Economic evaluation of zinc and copper use in treating acute diarrhea in children: A randomized controlled trial. Cost.Eff.Resour.Alloc. *1*, 7.

Popkin,B.M. (2002). An overview on the nutrition transition and its health implications: the Bellagio meeting. Public Health Nutr. *5*, 93-103.

Popratiloff,A., Giaume,C., and Peusner,K.D. (2003). Developmental change in expression and subcellular localization of two shaker-related potassium channel proteins (Kv1.1 and Kv1.2) in the chick tangential vestibular nucleus. J.Comp Neurol. *461*, 466-482.

Porras,I., Thompson,J., Tumwine,J., Mujwahuzi,M., and Katua-Katua,M. The costs of water for domestic use in east africa: thirty years of change. 2001.

Poskitt,E.M., Cole,T.J., and Whitehead,R.G. (1999). Less diarrhoea but no change in growth: 15 years' data from three Gambian villages. Arch.Dis.Child *80*, 115-119.

Powanda,M.C. and Beisel,W.R. (2003). Metabolic effects of infection on protein and energy status. J.Nutr. *133*, 322S-327S.

Powles,J. and Day,N. Interpreting the global burden of disease. commentary to Ezzati et al Lancet, 2002,360:1347-60 ID136 . 2002.

Pronk,j. Meeting the MDG targets on Water and sanitation. 12th International conference on`Health and Environment:Global Partners for Global Solutions, 1-13. 2003. 4-24-2003.

Pruss,A., Kay,D., Fewtrell,L., and Bartram,J. (2002). Estimating the burden of disease from water, sanitation, and hygiene at a global level. Environ.Health Perspect. *110*, 537-542.

Quick,R. (2003). Changing community behaviour: experience from three African countries. Int.J.Environ.Health Res. *13 Suppl 1:S115-21.*, S115-S121.

Ramakrishnan,U. (2002). Prevalence of micronutrient malnutrition worldwide. Nutr.Rev. *60*, S46-S52.

Ray,S.K., Haldar,A., Biswas,B., Misra,R., and Kumar,S. (2001). Epidemiology of undernutrition. Indian J.Pediatr. *68*, 1025-1030.

Report by the Secretariat. Infant and young child nutrition Global strategy on infant and young child feeding. 2002.

Rice,A.L, Sacco,L.,Hyder,A., Black,R.E. (2000). Malnutrition as an underlying cause of childhood deaths associated with infectious diseases in developing countries. Bull.World Health Organ *78*, 1207-1221.

Riddell,A. and Pollard,A.J. (2003). Tropical disease vaccines. Expert.Rev.Vaccines. *2*, 105-112.

Rosenberg,I.H. (2003). Tropical enteritis: nutritional consequences and connections with the riddle of cholera. J.Nutr. *133*, 333S-335S.

Rotavirus Vaccine. Rotavirus Vaccine: Preventing severe diarrheal disease in infants. 8-11. 1999.

Rousham,E.K. and Gracey,M. (1997). Persistent growth faltering among aboriginal infants and young children in north-west Australia: a retrospective study from 1969 to 1993. Acta Paediatr. *86*, 46-50.

Rowland,M.G., Cole,T.J., and Whitehead,R.G. (1977). A quantitative study into the role of infection in determining nutritional status in Gambian village children. Br.J.Nutr. *37*, 441-450.

Rowland,M.G. (1986). The weanling's dilemma: are we making progress? Acta Paediatr.Scand.Suppl *323:33-42.*, 33-42.

Rowland,M.G., Rowland,S.G., and Cole,T.J. (1988). Impact of infection on the growth of children from 0 to 2 years in an urban West African community. Am.J.Clin.Nutr. *47*, 134-138.

Roy,S. and Ray,S. (2000). Prevention of malnutrition. J.Indian Med.Assoc. *98*, 510-511.

Roy,S.K., Tomkins,A.M., Mahalanabis,D., Akramuzzaman,S.M., Haider,R., Behrens,R.H., and Fuchs,G. (1998). Impact of zinc supplementation on persistent diarrhoea in malnourished Bangladeshi children. Acta Paediatr. *87*, 1235-1239.

Rush,D. (2001). Maternal nutrition and perinatal survival. Nutr.Rev. *59*, 315-326.

Rutstein,S.O. (2000). Factors associated with trends in infant and child mortality in developing countries during the 1990s. Bull.World Health Organ *78*, 1256-1270.

Santamaria,J. and Toranzos,G.A. (2003). Enteric pathogens and soil: a short review. Int.Microbiol. *6*, 5-9.

Sazawal,S., Black,R.E., Menon,V.P., Dinghra,P., Caulfield,L.E., Dhingra,U., and Bagati,A. (2001). Zinc supplementation in infants born small for gestational age reduces mortality: a prospective, randomized, controlled trial. Pediatrics *108*, 1280-1286.

Schiller,L.R. (1999). Secretory diarrhea. Curr.Gastroenterol.Rep. *1*, 389-397.

Schoenen,D. (2002). Role of disinfection in suppressing the spread of pathogens with drinking water: possibilities and limitations. Water Res. *36*, 3874-3888.

Scrimshaw,N.S., Taylor,C.E., and Gordon,J.E. (1968). Interactions of nutrition and infection. Monogr Ser.World Health Organ *57:3-329.*, 3-329.

Scrimshaw,N.S. (2003). Historical concepts of interactions, synergism and antagonism between nutrition and infection. J.Nutr. *133*, 316S-321S.

Sellen,D.W. (2001). Comparison of infant feeding patterns reported for nonindustrial populations with current recommendations. J.Nutr. *131*, 2707-2715.

Shah,S.M., Yousafzai,M., Lakhani,N.B., Chotani,R.A., and Nowshad,G. (2003). Prevalence and correlates of diarrhea. Indian J.Pediatr. *70*, 207-211.

Shao,M., Hirsch,J.C., Giaume,C., and Peusner,K.D. (2003). Spontaneous synaptic activity is primarily GABAergic in vestibular nucleus neurons of the chick embryo. J.Neurophysiol. *90*, 1182-1192.

Simondon,K.B., Simondon,F., Costes,R., Delaunay,V., and Diallo,A. (2001). Breast-feeding is associated with improved growth in length, but not weight, in rural Senegalese toddlers. Am.J.Clin.Nutr. *73*, 959-967.

Smet J. Domestic Rainwater Harvesting. 1-4. 2003. Well Fact Sheet march 2003.

Snel,M. School Sanitation and Hygiene Education. Thematic overview paper IRC International water and sanitationCentre. 1-50. 2003.

Sobsey,M.D., Handzel,T., and Venczel,L. (2003). Chlorination and safe storage of household drinking water in developing countries to reduce waterborne disease. Water Sci.Technol. *47*, 221-228.

Solis,B., Samartin,S., Gomez,S., Nova,E., de la,R.B., and Marcos,A. (2002). Probiotics as a help in children suffering from malnutrition and diarrhoea. Eur.J.Clin.Nutr. *56 Suppl 3:S57-9.*, S57-S59.

Sripaipan,T., Schroeder,D.G., Marsh,D.R., Pachon,H., Dearden,K.A., Ha,T.T., and Lang,T.T. (2002). Effect of an integrated nutrition program on child morbidity due to respiratory infection and diarrhea in northern Viet Nam. Food Nutr.Bull. *23*, 70-77.

Stephenson,L.S., Latham,M.C., and Ottesen,E.A. (2000). Global malnutrition. Parasitology *121 Suppl:S5-22.*, S5-22.

Strina,A., Cairncross,S., Barreto,M.L., Larrea,C., and Prado,M.S. (2003). Childhood diarrhea and observed hygiene behavior in Salvador, Brazil. Am.J.Epidemiol. *157*, 1032-1038.

Swallow,D.M. (2003). Genetics of lactase persistence and lactose intolerance. Annu.Rev.Genet. *37:197-219.*, 197-219.

Thompson,J., Porras,I., Tumwine,J.K., Mujwahuzi,M., Katui-Katua,M., Johnstone,N., and wood I. Drawers of water II (30 years of change in domestic use & environmental health in east africa). Thompson, J. 2001.

Thompson,J. and Cairncross,S. (2002). Drawers of water:assessing domestic use of water in Africa. Bull.World Health Organ *80*, 61-62.

Thompson,T., Sobsey,M., and Bartram,J. (2003). Providing clean water, keeping water clean: an integrated approach. Int.J.Environ.Health Res. *13 Suppl 1:S89-94.*, S89-S94.

Tomar,B.S. (2001). Intestinal infections. Indian J.Pediatr. *68 Suppl 3:S8-18.*, S8-18.

Tomkins,A. (2000). Malnutrition, morbidity and mortality in children and their mothers. Proc.Nutr.Soc. *59*, 135-146.

Tompson,M., LeVan,F.J., Eastman,A., McClain,V.W., and Morrison,P. (2002). Exclusive breastfeeding is best in all cases. Bull.World Health Organ *80*, 605.

Tonglet,R., Mahangaiko,L.E., Zihindula,P.M., Wodon,A., Dramaix,M., and Hennart,P. (1999). How useful are anthropometric, clinical and dietary measurements of nutritional status as predictors of morbidity of young children in central Africa? Trop.Med.Int.Health *4*, 120-130.

Tumwine,J., Thompson,J., Katui-Katua,M., Mujwahuzi,M., Johnstone,N., and Porras,I. (2002). Sanitation and hygiene in urban and rural households in East Africa. Int.J.Environ.Health Res. *13*, 107-115.

Tumwine,J.K., Thompson,J., Katua-Katua,M., Mujwajuzi,M., Johnstone,N., and Porras,I. (2002). Diarrhoea and effects of different water sources, sanitation and hygiene behaviour in East Africa. Trop.Med.Int.Health *7*, 750-756.

Ukwuani,F.A. and Suchindran,C.M. (2003). Implications of women's work for child nutritional status in sub-Saharan Africa: a case study of Nigeria. Soc.Sci.Med. *56*, 2109-2121.

Underwood,B.A. (2003). Scientific research: essential, but is it enough to combat world food insecurities? J.Nutr. *133*, 1434S-1437S.

UNICEFwaterfront (2003). Safe water and basic sanitation for every family as a human right. Waterfront 1-28.

UNICEF. VITAMIN & MINERAL DEFICIENCY A Global Progress Report. UNICEF. 1-9. 2004.

Van der Hoek W., Konradsen,F., Ensink,J.H., Mudasser,M., and Jensen,P.K. (2001). Irrigation water as a source of drinking water: is safe use possible? Trop.Med.Int.Health *6*, 46-54.

Van der Hoek W., Feenstra,S.G., and Konradsen,F. (2002). Availability of irrigation water for domestic use in Pakistan: its impact on prevalence of diarrhoea and nutritional status of children. J.Health Popul.Nutr. *20*, 77-84.

Victora,C.G., Smith,P.G., Vaughan,J.P., Nobre,L.C., Lombardi,C., Teixeira,A.M., Fuchs,S.C., Moreira,L.B., Gigante,L.P., and Barros,F.C. (1988). Water supply, sanitation and housing in relation to the risk of infant mortality from diarrhoea. Int.J.Epidemiol. *17*, 651-654.

Victora,C.G., Smith,P.G., Vaughan,J.P., Nobre,L.C., Lombardi,C., Teixeira,A.M., Fuchs,S.M., Moreira,L.B., Gigante,L.P., and Barros,F.C. (1988b). Influence of birth weight on mortality from infectious diseases: a case-control study. Pediatrics *81*, 807-811.

Viteri,F.E. and Gonzalez,H. (2002). Adverse outcomes of poor micronutrient status in childhood and adolescence. Nutr.Rev. *60*, S77-S83.

Weaver,L.T. Commentary to:Less diarrhoea but no change in growth: 15years' data from three Gambian villages Poskitt et al 1999 ID63. Arch.Dis.Child 80, 115. 1999.

White,G.F., Bradley,D.J., and White,A.U. Drawers of Water (Domestic Water Use in East Africa). reproduced by permission of the University of Chicago Press, 63-73. 2003.

WHO opt.BreastF... The optimal duration of exclusive breastfeeding. Fifty-fourth World Health Assembly 54.2, Provisional Agenda item 13.1, 1 may 2001 A54/INF.DOC./4, 1-5. 2001.

WHOcoll (2000). Effect of breastfeeding on infant and child mortality due to infectious diseases in less developed countries: a pooled analysis. WHO Collaborative Study Team on the Role of Breastfeeding on the Prevention of Infant Mortality. Lancet *355*, 451-455.

Wibowo,D. and Tisdell,C. (1993). Health, safe water and sanitation: a cross-sectional health production function for central Java, Indonesia. Bull.World Health Organ *71*, 237-245.

Wilhelmi,I., Roman,E., and Sanchez-Fauquier,A. (2003). Viruses causing gastroenteritis. Clin.Microbiol.Infect. *9*, 247-262.

Zoysa de,I. and Feachem,R.G. (1985). Interventions for the control of diarrhoeal diseases among young children: rotavirus and cholera immunization. Bull.World Health Organ *63*, 569-583.