International Institute for Environment and Development

Sustainable Agriculture and Rural Livelihoods Programme

GATEKEEPER SERIES No. 5

The Blue Baby Syndrome and Nitrogen Fertilisers: A High Risk in the Tropics?

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This Gatekeeper Series is produced by the International Institute for Environment and Development to highlight key topics in the field of sustainable agriculture. Each paper reviews a selected issue of contemporary importance and draws preliminary conclusions of relevance to development activities. References are provided to important sources and background material.

The Swedish International Development Authority (SIDA) funds the series, which is aimed especially at the field staff, researchers and decision makers of such agencies.

THE BLUE BABY SYNDROME AND NITROGEN FERTILISERS:
A HIGH RISK IN THE TROPICS?

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Nitrates taken in with water or food can result in methaemoglobinaemia, commonly known in infants as the blue-baby syndrome. The body becomes progressively starved of oxygen, turning affected individuals blue, firstly around the lips, fingers and toes and then spreading to the face and body. Under normal conditions haemoglobin in the blood passes through a well-balanced cycle of picking up oxygen in the lungs and releasing it to the body's tissues. But the process is disrupted if alternative oxidising agents are present. These combine with haemoglobin to form methaemoglobin, so preventing it from transporting oxygen. Nitrites, which are formed in the body from nitrates by the action of some bacteria, will oxidise haemoglobin in this way. When more than 5% of haemoglobin is converted to methaemoglobin, clinical symptoms of oxygen starvation begin to occur; by 30-40% the body is acutely short of oxygen, and at over 50% death usually occurs.

Since the condition of methaemoglobinaemia was first recognised over 40 years ago, some 3000 cases have been reported worldwide. Although the great majority occurred in the period to 1965, recent cases and deaths have been reported in intensive agricultural regions in the USA and Hungary. However, there are very few records of the blue-baby syndrome in infants in tropical countries. Indeed only one study is reported in the literature. This found a high incidence of methaemoglobinaemia among children from a rural area of Namibia. Out of nearly 500 infants under one year old, about 8% had blood levels of more than 5% methaemoglobin. One infant, close to death with a level of 35% blood methaemoglobin, was found to have been consuming water containing 250 mg nitrate/litre[1]. The population was almost entirely dependent on ground wells for drinking water and 40% of the infants regularly consumed water at concentrations greater than 90mg nitrate/1. The source of the contamination, though, was probably livestock waste rather than fertiliser.

The blue-baby syndrome thus appears to be rare in tropical countries. Nonetheless, a closer look at the reasons for the higher susceptibility in infants – methaemoglobinaemia very rarely occurs in adults – and the health and hygiene conditions particular to the tropics suggest that it would be wrong to be complacent.

Infants are particularly susceptible because they are more likely to take up high levels of

1. Concentrations are exclusively given in terms of nitrate levels. In other sources they may be given as nitrate-nitrogen. To convert from nitrate to nitrate-N, simply multiply by a factor of 0.226.
For example: 45 mg nitrate = 10 mg nitrate-N

nitrates in food or drinking water. Nitrate is present in all crop plants, but levels vary considerably, according to the type of crop, the growing conditions and the amounts of nitrogen fertiliser applied. Levels are particularly high in leafy crops, such as spinach and cabbage, and certain roots, such as turnip and carrot. Some cases of the blue-baby syndrome have arisen in infants consuming spinach or carrot juice. Most cases, though, result from consumption of water containing more than 100mg nitrate/1, particularly when the water is used to make up dried milk products as a substitute for breast feeding. Infants are also particularly susceptible because they require up to ten times the fluid per unit of body weight compared with adults, and are thus likely to consume more nitrate. Repeated boiling of water, although destroying bacteria, increases the nitrate concentration. By contrast, breast feeding poses a lower risk since nitrates do not become concentrated in breast milk.

Vitamin C is a further factor since it causes methaemoglobin to change back to haemoglobin. This is particularly important in infants for two reasons. The type of haemoglobin particular to the foetus persists for a while in the blood stream of babies and is especially susceptible to oxidation to methaemoglobin by nitrite. Young infants also have only small quantities of the particular blood enzyme which reduces methaemoglobin.

Of equal importance to the quantity of nitrates ingested is the degree of bacterial contamination of water or foods. Although many strains of common bacteria are capable of reducing nitrate to nitrite, they can only operate under conditions of low acidity, such as in the saliva and the lower intestine. In adults the stomach is acidic most of the time, and bacteria cannot survive. But in infants, because the stomach is less acidic, it can be colonised by bacteria from the mouth or lower intestine, or from the consumption of contaminated water.

The blue-baby syndrome is also often associated with diarrhoea and gastero-enteritic upsets. Infants suffering from diarrhoea usually have a higher gastric pH than normal infants, and some strains of acutely pathogenic organisms, such as *Salmonella*, *Shigella* and *Vibrio* (cholera), are nitrate reducers. Diarrhoea causes 5–10 million mortalities annually, but it is not known how many of these cases result from pathogens also capable of reducing nitrates. Risk may be further enhanced by the use of some anti-diarrhoeal treatments that are high in nitrate, such as bismuth subnitrate.

High nitrate levels in drinking water in developing countries are known to occur. According to various surveys in India and Africa, some 20–50% of wells contain nitrate levels greater than 50mg/l[2] and, in some cases, as high as several hundred mg/l. But apart from surface waters in the vicinity of fertiliser factories, it is usually wells in villages or close to towns that contain the highest nitrate levels, suggesting that domestic excreta are the main source rather than fertilisers. Livestock wastes also tend to be important where drinking water troughs are situated close to wells, often producing levels in the hundreds of mg/1.

The situation is thus currently in marked contrast to developed countries, where the source of a significant proportion of nitrate appears to be inorganic nitrogen fertilisers.

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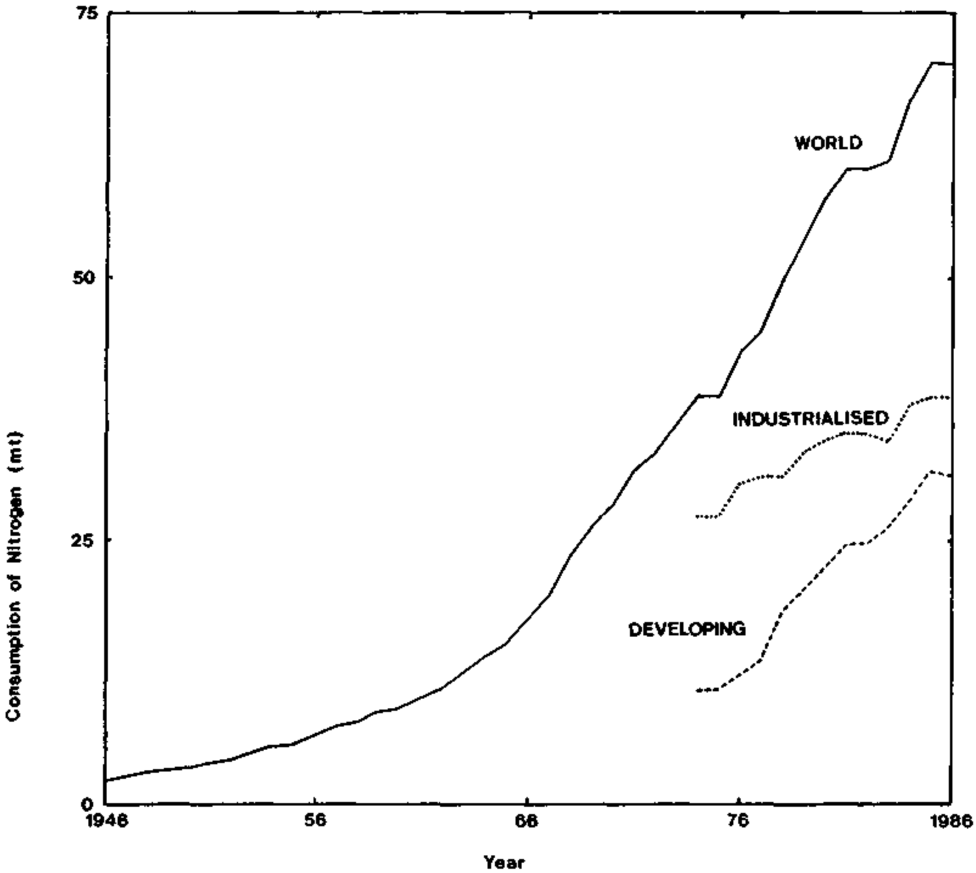
2. The WHO guideline for safe levels in drinking water is 45 mg nitrate/litre.

The question that urgently needs answering is: are the necessary conditions which combine to bring about the blue-baby syndrome more likely to occur in the tropics? In particular, **is there a high risk in the tropics?**

At present there are only partial answers. First, average nitrogen fertiliser rates to arable land are still a great deal lower in developing countries than in industrialised: regional averages are about 30kg nitrogen/hectare for Asia, 15kg for Latin America and 4kg for Africa, compared with averages of 188kg for western Europe and 146kg for Japan. Nonetheless, most of the recent increase has occurred in the developing countries where, since 1976, nitrogen consumption has grown by 230% compared with only 25% in the industrialised (Figure 1).

Figure 1 Nitrogen fertiliser consumption, 1946–1986



Much of this growth has been associated with the introduction of new 'Green Revolution' cereal varieties, capable of producing high yields with heavy fertiliser applications. In some of the intensive rice and wheat growing regions average application rates are now approaching those of the industrialised countries.

The risks of nitrate contamination of water are highest in such regions, particularly in seasonal climates where nitrates are flushed into surface and ground water at the onset of the rainy season, and where irrigation water both provides a direct conduit for nitrate to surface and ground water, and may help progressively to concentrate nitrate levels during reuse. Future growth in crop production, which will be necessary to feed a growing world population, will have to come from intensification, and this currently implies increasing fertiliser use.

Second, at least in theory, the prevailing health and hygiene in the tropics poses a higher risk. Breast feeding confers some resistance to both the blue-baby syndrome and diarrhoea, but increasing use of dried milk products requiring preparation with locally available water is likely to increase risk. Diarrhoea itself is common, and diets are often poor in vitamin C. Blue-baby syndrome could, therefore, be far more prevalent than is supposed. It may be that infants are dying from diarrhoea before signs of methaemoglobinaemia have time to develop. Close investigation of existing situations with very high nitrate levels resulting from domestic and livestock wastes might provide some indication of the present and potential incidence of the disease.

Several options are available if the risk of the blue-baby syndrome is to be reduced or avoided. Clearly promotion of breast feeding, vitamin C supplements and potable water supplies are critical. However, justifying a reduction in fertiliser use to restrict possible nitrate pollution is more contentious, given its importance to food production and the role of domestic and livestock wastes in water contamination. In the meantime greater effort should be devoted to the promotion of more efficient and less polluting use of nitrogen fertilisers and to biological sources of nitrogen, including the use of crop wastes, livestock and green manure, legumes in rotation and as tree crops, and the exploitation of blue-green algae and nitrogen fixing bacteria in rice paddies.

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Sustainable Agriculture and Rural Livelihoods Programme

The Sustainable Agriculture and Rural Livelihoods Programme

The Sustainable Agriculture and Rural Livelihoods Programme of IIED promotes and supports the development of socially and environmentally aware agriculture through policy research, training and capacity strengthening, networking and information dissemination, and advisory services.

The Programme emphasises close collaboration and consultation with a wide range of institutions in the South. Collaborative research projects are aimed at identifying the constraints and potentials of the livelihood strategies of the Third World poor who are affected by ecological, economic and social change. These initiatives focus on the development and application of participatory approaches to research and development; resource conserving technologies and practices; collective approaches to resource management; the value of wild foods and resources; rural-urban interactions; and policies and institutions that work for sustainable agriculture.

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