The impact of consuming iron from non-food sources on iron status in developing countries

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Abstract

Objective: To determine the impact of contaminant iron and geophagy on iron intake and status of persons living in developing countries.

Design: Literature for review was identified by searching Medline and Agricola, from appropriate other texts and from three reports from the Opportunities for Micronutrient Interventions (OMNI) Project of USAID.

Setting: The dietary intake of iron by people living in developing countries is generally high but iron deficiency remains prevalent. This apparent paradox is because the iron being consumed is predominantly in the non-haem form, which is poorly absorbed. Some of this non-haem iron is from contamination of food with iron from soil, dust and water; iron leaching into food during storage and cooking; contamination during food processing such as milling; and the practice of geophagy.

Results: Although the contribution of contaminant iron to overall iron intake is well documented, its absorption and thus its impact on iron status is not. To be available for absorption, contaminant iron must join the common non-haem pool, i.e. be exchangeable. The absorption of exchangeable contaminant iron is subject to the same interactions with other constituents in the diet as the non-haem iron that is intrinsic to food. The limited available evidence suggests wide variation in exchangeability. In situations where a significant fraction of the contaminating iron joins the pool, the impact on iron status could be substantial. Without a simple method for predicting exchangeability, the impact of contaminant iron on iron status in any particular situation is uncertain.

Conclusions: Interventions known to increase the absorption of iron intrinsic to foods will also increase absorption of any contaminant iron that has joined the common pool. Any positive effect of geophagy resulting from an increased intake of iron is highly unlikely, due to inhibiting constituents contained in soils and clays. The efficacy of approaches designed to increase the intake of contaminant iron remains encouraging but uncertain. An approach using multiple interventions will continue to be essential to reduce iron deficiency anaemia.

Keywords
Iron nutrition
Iron absorption
Iron bioavailability
Geophagy
Public health iron interventions

Iron deficiency is prevalent in developing countries[1] despite diets that are generally high in iron[2,3]. This is because meals that are unfavourable to the absorption of the iron consumed, i.e. diets that contain constituents that inhibit absorption (such as phytates and tannins) are low in constituents that enhance absorption (e.g. meat, fish, ascorbic acid) and contain predominantly non-haem iron which is relatively unavailable for absorption. A significant proportion of the iron in the diets of developing countries is extrinsic to food, usually referred to as contaminant iron[3–6], but the impact of this iron on iron status is controversial.

The practice of geophagy, the deliberate and regular eating of soil or clay, has been suggested both as a cause and a consequence of iron deficiency[7,8]. However, others have found no association between the practice and iron status[9,10]. Since geophagy is common in areas where iron deficiency is prevalent[7], an assessment of the impact of the practice on iron status would be useful to those developing programmes designed to reduce iron deficiency.

This review will address three questions in relation to interventions designed to improve the iron status of populations in developing countries:

1. What is the impact of consuming contaminant iron on overall iron intake and iron status?
2. What is the impact of geophagy on iron status?
3. What conclusions regarding the consumption of contaminant iron and the practice of geophagy can be

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drawn in relation to programmes aiming to improve iron status?

Literature for the review was identified by searching the Medline and Agricola databases. The search was restricted to English language papers and the selection of articles identified from the search focused on issues relevant to developing countries. In addition, text books on iron and its absorption[3,11,12], reports prepared for the OMNI Project for USAID on the bioavailability of iron in food by Allen and Ahluwalia[13], geophagy[14] and the proceedings of a conference on iron status[15] were reviewed. Studies which were reported only as abstracts in the conference proceedings were excluded.

Classification of dietary iron

All iron consumed in the diet is either haem or non-haem and is absorbed from two distinct pools in the lumen of the gastrointestinal tract, largely in the small intestine[3]. Haem iron comes from animal foods and is absorbed relatively well, its absorption being largely independent of other constituents in the diet. Haem iron is not considered further in this review. The chemistry of non-haem iron from animal and plant sources has been described in detail by Hazell[16]. All non-haem iron from plant sources is believed to join the common non-haem pool, but that from animal sources, mainly ferritin and hemosiderin, may not[3].

A classification of non-haem iron that is extrinsic to food is shown in Fig. 1. All of the haem iron joins the common pool of haem iron. With non-haem iron it is presumed that all the non-haem iron intrinsic to plant food joins the common non-haem iron pool. An unknown percentage joins this non-haem iron pool from animal foods' non-haem iron, and sources extrinsic to foods such as that in contaminant soil. Sources of iron extrinsic to food include: contamination of foods from soil, dust and water; metal fragments from milling; that leached from iron or steel pots during processing, storage or cooking; the practice of geophagia; and iron from supplements or fortificants (the last two are not considered in this review). These contaminant forms of iron are largely ferric hydroxide and ferric oxide, but they are likely to vary widely in terms of solubility and affinity for reaction with other compounds.

For contaminant iron to be absorbed it must first join the common pool of non-haem iron and to do this, it must be soluble at the pH of the small intestine. Factors determining the solubility of the iron are critical for iron to be available for absorption. The absorption of non-haem iron from the common pool, whether originally intrinsic or

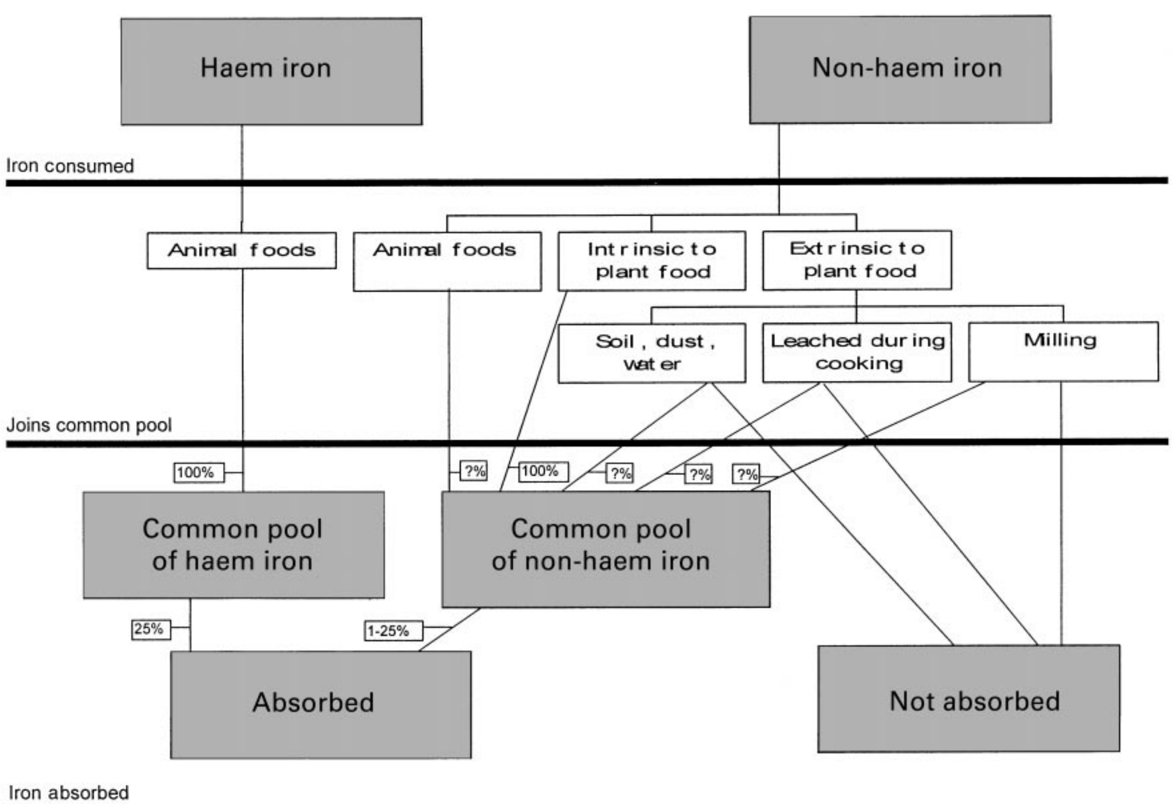

Fig. 1 Non-haem iron in the diet extrinsic to food showing common pools of haem and non-haem iron in relation to absorption percentages taken (from Bothwell *et al.*[3])

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extrinsic to food, is subject to the same interactions with other constituents of the diet, as well as to endogenous factors of the host such as the nature of gastric secretions, transit time, rate of erythropoiesis and the size of existing iron stores[13,17,18]. Despite intensive research effort since the 1960s, the understanding of iron absorption is still not complete[19].

The bioavailability of non-haem iron in a laboratory setting has been estimated to differ by up to 15-fold[17]. In developing countries, where contaminant iron contributes significantly to iron intake, the range of bioavailability of the non-haem iron consumed will be even greater than this because the faction of the contaminant iron that joins the non-haem pool, called its exchangeability[20], varies widely.

Does contaminant iron contribute significantly to iron intake?

The significant contribution of contaminant iron to total iron intake has been well documented. Beaton[2] presented data from the analyses of food from over 20 countries showing that the actual iron content of diets was as much as double that expected on the basis of calculations from food composition tables. He concluded that most of the additional iron was of extrinsic origin, from food containers or other surfaces, or dirt. A frequently quoted example of extreme contamination in food is the level of iron in teff, a small-grained Ethiopian cereal traditionally threshed under the hooves of cattle. Contributions from teff of as much as 200–500 mg of iron daily have been recorded[3], the bulk of which was attributed to contaminating soil.

The classic evidence of extrinsic iron contributing substantially to dietary intake is the report by Charlton *et al.*[21] of dietary iron overload from consumption of locally brewed beers in South Africa. The reported iron concentrations in the beer ranged from 3 to 10 mg 100 ml^{-1} and since large volumes of this relatively low alcohol beer were consumed, the resulting daily iron intakes were estimated to be 50–100 mg.

Several studies confirming the iron contamination of food cooked in iron pots have been reported more recently. Liu *et al.*[22] investigated the levels of iron in foods cooked in Chinese iron pots and reported two- to five-fold increases in iron content over foods cooked in aluminium, stainless steel and clay pots. Evidence of iron contamination of food cooked in an iron skillet has been provided for foods typically consumed in the USA[23], for Chinese foods cooked in a steel wok[24] and for Indian foods prepared in iron pots[25]. Acidity, moisture content and cooking time increased this iron contamination in each of these studies. A study comparing Ethiopian foods cooked in iron, aluminium and clay pots, found that there was 'more crude iron in all foods cooked in iron pots – around twice as much iron in meat and vegetables, and 1.5 times as much iron in legumes – than in food cooked in the other two types of pot'[26].

While nutritionists are interested in the leaching into foods of metals that are nutrients, toxicologists investigate the leaching of other metals that can be toxic. It has been reported that nickel as well as the nutrients iron and chromium leach into foods when cooked in stainless steel utensils[27,28]. This is a concern since nickel has been implicated in skin sensitivities such as hand eczema. Kuligowski and Halperin[27] also noted differences in the chemical composition of the stainless steels manufactured in different countries as well as the varying extent to which minerals leach from them. These findings are pertinent to public health planners who need to be cautious in making recommendations about the use of such utensils. Flint and Packirissrey[29] reported that significant leaching of nickel was restricted to first use of stainless steel utensils.

In studies to determine the absorption of contaminant iron, Hallberg and Bjorn-Rasmussen[20] measured the amounts of contaminant iron in rice flour and teff (Table 1). They found that a sample of rice flour purchased in a Thai market contained 30 mg iron 100 g^{-1}, substantially more than the 1.4 mg 100 g^{-1} found in polished rice purchased in the same market. The total iron content of a sample of teff was 39.7 mg 100 g^{-1}, compared to only 3.5 mg 100 g^{-1} present after careful washing with hydrochloric acid. These findings highlight the importance of considering contaminant iron in any assessment of iron intake in developing countries.

In summary, there is substantial evidence that contaminant iron contributes significantly to iron intake in developing countries, but the significance of this intake for iron status is clearly dependent on the extent to which the contaminant iron is absorbed.

Table 1 Exchangeability of non-haem iron in selected soils and foods (data from Hallberg & Bjorn-Rasmussen[20])

Sample	Total non-haem iron* (mg 100 g^{-1})	Contaminant iron (mg 100 g^{-1})	Exchangeability (%) of contaminant iron†
Red soil (Brazil)	9430	9430	0
Clay 1 (Thailand)	3130	3130	35
Clay 2 (Thailand)	2270	2270	22
Polished rice (Thailand)	1.4	–	–
Rice flour (Thailand)	30	29	35
Teff (Ethiopia)	40	36	3

* Includes inherent non-haem iron in food and extraneous contaminant iron from dirt, milling, etc.
† The proportion of contaminant iron that joins the common pool and hence becomes available for absorption.

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How much of the contaminant or other extrinsic iron is absorbed?

The description of iron overload by Charlton *et al.*[21] leaves no doubt that the iron from vessels used for brewing traditional beer in South Africa can be absorbed, but this finding should not be generalised to other situations where iron contaminates food. Firstly, the quantities of iron consumed in the brews were enormous – more than 100 mg day^{-1} in a quarter of the men. Secondly, low pH, the presence of lactic acid, the alcohol content and the removal of solids from the brews, all contributed independently to increase absorption[30]. Lastly, this population may be unique with respect to a gene for iron overload[31,32].

A valid measure of the absorption of non-haem iron from a meal can be made in a laboratory setting by adding a known amount of isotope iron to the meal, an 'extrinsic tag', and measuring the proportion of this which is absorbed[3]. Using such a method, Derman *et al.*[30,33] investigated the absorption of ferric oxide and ferric hydroxide, which are the most common compounds of contaminant iron. These compounds were prepared in the laboratory to simulate contaminant iron and were added to maize-meal porridge. Absorption was poor – 0.01% and 1.5%, respectively – but was increased substantially by adding ascorbic acid to the meal. No other study reporting the absorption of contaminant iron alone was found in this review, but there remains some uncertainty about the extent to which these findings with a simulated contaminant iron reflect the absorption of contaminant iron outside the laboratory setting.

The extrinsic tag method assumes complete isotopic exchange between the inorganic labelled iron tracer added to food and the non-haem iron in the food. This assumption holds for non-haem iron that is intrinsic to food, i.e. this iron exchanges completely (100%) with the tracer. Contaminant iron is different from non-haem iron that is intrinsic to food in that it does not exchange completely with the tracer (see Fig. 1). This limits the validity of the extrinsic tag method in developing countries where iron contamination is common.

In a meal, the proportion of non-haem iron that exchanges with the extrinsic tag is the same as the proportion that joins the common non-haem iron pool. Hallberg and Bjorn-Rasmussen[20] called this the 'exchangeability' of the iron and developed an *in vitro* method to assess it. In this method food is digested with pepsin and trypsin in the presence of radioiron. The exchangeability of the food is calculated from the specific activity in the food and in an extract of bathophenantroline in isoamyl alcohol obtained after digesting the food. These authors described the exchangeability of iron in samples of soil, rice flour and teff (Table 1). Addition of increasing amounts of a sample of red soil from Brazil did not increase the amount of exchangeable iron in a meal, i.e. the exchangeability of the iron in this soil was zero. When clay from a rice field in central Thailand was added to the meal, there was a linear increase in the amount of iron exchanged. The amount of iron exchanged was calculated from the slope of this line to be 35%. Ninety-five per cent of the iron in a sample of rice flour purchased in a Bangkok market was estimated to be contaminant iron and 35% of this was found to be exchangeable. The teff from Ethiopia was also heavily contaminated with iron, but only 3% of this iron exchanged with the tracer. The absorption of the contaminant iron in the samples that did exchange was not reported, but theoretically it would be the same as that for the non-haem iron intrinsic to food since the same factors determine absorption of all iron in the common pool.

The method of Hallberg and Bjorn-Rasmussen[20] has been used to describe exchangeability, and has been used together with the extrinsic tag method to study the absorption of total non-haem iron in Asian and African meals. Table 2 shows that between 50% and 96% of the total non-haem iron in a variety of Asian meals was exchangeable with an extrinsic tag[4]. Since some, but an unknown amount, of the contaminant iron present in the meals was probably exchanged with the isotope, these results support the conclusion that the proportion of iron from contamination in these meals ranged from a minimum of 4% (100 − 96) for the Chinese 1 meal to more than 50% (100 − 50) for the Thai 2 meal (Table 2). These meals

Table 2 Exchangeability and absorption of total non-haem iron from six Asian meals (data from Hallberg *et al.*[4])

Meal	Weight (g)	Total non-haem iron* (mg)	Exchangeability† (%)	Absorption‡ (%)
Chinese 1	230	3.4	96	17
Chinese 2	277	3.0	54	10
Chinese 3	195	5.9	64	4
Thai 1	370	3.6	67	24
Thai 2	250	2.0	50	20
Indian	130	5.1	72	9

* Includes inherent non-haem iron in food and extraneous contaminant iron from dirt, milling, etc.
† The proportion of total non-haem iron that joins the common pool and hence becomes available for absorption.
‡ Absorption corrected to 40% absorption from a reference dose.

were prepared in the normal way for an urban South East Asian population with usual techniques for cleaning and rinsing foods. It is likely that the amount of contaminant iron is much larger at the village level. Absorption of the exchanged iron in these meals (contaminant and intrinsic iron together) varied from 4% to 24%, which is relatively high because the composition of the diets favoured absorption.

The same technique was used to determine the amount of exchangeable iron in West African foods and the results were similar to those reported for Asian foods. Guiro and Hercberg[34] determined that 20–90% of the total non-haem iron in millet meals typical of those prepared in Senegal exchanged with the tracer, i.e. contaminant iron comprised at least 10% to more than 80% of the total non-haem iron present. In further studies of the absorption of iron from meals made from local millet and imported rice, Guiro *et al.*[35] reported that up to 60% of the total non-haem iron did not exchange with the added inorganic tracer and that absorption from the iron that did exchange was low, ranging from 1.2% for the millet gruel to 10.4% for the rice and fish meal. Similar studies with three types of meals based on maize, typical of the diets of people living in South Benin, showed that between 39% and 73% of the non-haem iron did not exchange, and the absorption of the iron that did exchange ranged from 1.2% to 3.2%[6].

The reports of the studies from South East Asia and Africa suggest wide variations in the amounts of contaminant iron in foods and also in the proportion of contaminant iron that joins the non-haem iron pool to become available for absorption. No simple method of predicting the exchangeability of contaminant iron has been reported. None of the studies reported the absorption of the contaminant iron separately from that of the iron intrinsic to the foods. Further, this cannot be calculated, at least from the published reports, because the amounts of contaminant iron present in the meals were not reported.

Hurrell[36] has argued strongly that 'when making important public health and industrial decisions concerning the iron bioavailability from diets and individual foods, only experimental data supported by human experiments should be considered'. The limited number of studies reviewed above provide the only data found from studies directly addressing the extent to which contaminant iron is absorbed by humans. However, many other writers have drawn strong conclusions relative to the absorption of iron in humans based upon results from studies in animals and *in vitro* models.

In reporting their findings of contamination of food by iron from cookware, Brittin and co-workers stated unequivocally that this iron was bioavailable[23–25]. These authors justified their statement by citing *in vitro* work of Mistry *et al.*[37] and results from a rodent model by Martinez and Vannucchi[38]. However, neither of these studies took account of the complexities inherent in considering other constituents in the diet, a central issue in determining the relevance of scientific findings on iron absorption to planning public health programmes. Reddy and Cook[39] demonstrated other inadequacies of the rat model for extrapolating findings to the human context.

Svanberg[40] has also argued strongly that significant amounts of contaminant iron are absorbed. He cited the study by Derman *et al.*[41] to support his contention that contaminant iron in the form of ferric hydroxide was 'about one-half as well absorbed as the intrinsic iron in maize meal'. The study by Derman *et al.* used laboratory-prepared compounds to simulate contaminant iron. This review has found no discussion of the validity of this model. Regardless of the validity of this method, statements implying that the absorption of contaminating iron is consistent or predictable in different situations are not justified.

In summary, the absorption of iron from contaminating soil, dust and water is not well documented and thus its likely impact on iron status is not clear. Contaminant iron must join the common non-haem pool to be available for absorption and there is surprisingly little information on the extent to which this exchange occurs or on the factors that influence it. Evidence indicating wide variation has been presented and this variation seems largely unpredictable at this time. One study has demonstrated that ascorbic acid increases the exchange of ferric hydroxide[30]. The absorption of contaminant iron that does join the common pool is subject to the action of the same factors that determine the absorption of the non-haem iron that is intrinsic to food.

Until very recently, no convincing data from human studies have been found to show that the iron which leaches into food during storage or cooking has sufficient bioavailability to allow the expectation that an intervention based primarily on this approach would have a positive impact on iron status at a population level. However, a recent study has demonstrated that Ethiopian children fed food from iron pots had lower rates of anaemia and better growth than children whose food was cooked in aluminium or clay pots[26]. Further evidence is now required for the wider consideration of such programmes because those planning interventions must be assured of both efficacy and feasibility if implementation is to be successful. The studies of dietary iron overload from iron-contaminated beer clearly demonstrated that large amounts of contaminating iron can be absorbed. These findings, however, should not be generalised to other situations (e.g. where iron leaches into food), particularly in the light of recent studies suggesting an as yet unidentified 'iron-loading gene' in the population studied.

The impact of geophagy on iron status

Geophagy, the deliberate and regular eating of soil or clay, is a form of pica that has been described since antiquity, but its aetiology and biology have been surrounded by controversy[7,8,42]. Geophagy has been described as both a cause[43,44] and a consequence of anaemia[7,45].

The aetiology of geophagy remains uncertain. Danford[8] has described the four hypotheses most commonly discussed – nutritional, psychological, cultural and medical. The strongest support for the position that the practice is a response to a nutritional deficiency is in reports that dietary therapy results in its cessation. However, most of these reports are from case studies and lack appropriate controls. In a series of controlled trials evaluating this hypothesis, therapy with multivitamin and mineral preparations was no more effective than a placebo in eliminating or reducing the practice[46,47]. Despite these observations, Sayetta[48] concluded that there was sufficient indirect evidence to support a nutritional aetiology of geophagy, and this hypothesis appears to have wide current support[45,49].

Reid[42] proposed that culturally described geophagy be differentiated from 'idiosyncratic and culturally unsanctioned behavior such as eating of burnt matches, coffee grounds, large quantities of ice, or various other forms of pica found in the general population or among institutionalized mentally retarded patients'. Reid argued that the nature and circumstances of geophagy are too diverse to expect a single cause or consequence and that 'it would be surprising if it did not have some adaptive value … '[42]. Such an adaptive value was demonstrated by Vermeer and Ferrell[50] who described the use of clays in traditional West African medical preparations for problems associated with pregnancy and to ease stomach discomfort. Reid points out that such medical uses are not limited to 'folk medicine', since the clay kaolin is used in the pharmaceutical preparation Kaopectate (Upjohn Co., Kalamazoo, Michigan), amongst others, as an adsorbent in the treatment of diarrhoea. Johns and Duquette[51] showed that clays consumed in West Africa made astringent acorns more palatable by adsorbing large amounts of the tannic acid that occurs in the acorns, a further possible physiological benefit of the practice.

The practice of geophagy has the potential to affect iron status in three ways: (i) the iron in soil consumed might make a significant positive contribution to iron intake; (ii) constituents in soils and/or soil structure might chelate non-haem iron in the gastrointestinal tract to form insoluble complexes and thus reduce the overall absorption of iron; and (iii) the practice will contribute to helminth load if infective stages of the parasites are ingested with the soil. Recent studies in Kenya[52] have confirmed earlier studies showing geophagy to be associated with infection with geohelminths[53] and likely to be causal for ascariasis and possibly trichuriasis among primary school children. The first and the second of these potential effects will be affected by the type of food consumed at or close to the time of soil consumption.

The iron content of soil usually varies between 0.7 and 4.2%[54] and those soils at the higher end of this range could contribute significantly to iron intake. Johns and Duquette[51] analysed commonly consumed soils from West Africa and reported that they contained nutritionally significant amounts of a number of minerals including iron. But many believe that this iron is not bioavailable because the soil mineralogy limits its solubility in the intestine[3]. The consumption of foods containing chelating agents, such as ascorbic acid, at about the same time as the consumption of soil might maintain the iron in solution and hence result in some of it being absorbed, but this possibility has not been tested.

Different types of soils and clays have been shown to impact differently on iron absorption. In an *in vivo* study, Minnich *et al.*[44] demonstrated convincingly that soils consumed in Turkey had a marked negative impact on the absorption of radiolabelled ferrous sulphate in both normal and iron deficient subjects. In this study the soil and the ferrous sulphate were consumed at the same time. However, Talkington *et al.*[9] found that no such effect on iron absorption from the consumption of soils by pregnant women in Texas, and no association between geophagy and anaemia in pregnant women in rural Mississippi was found by Vermeer and Frate[10]. The timing of the consumption of soil in relation to consumption of other foods was not discussed in these studies.

The practice of geophagy in tropical countries is prevalent in areas where iron deficiency is common[7,55]. In the USA the practice has been reported as prevalent among some African-American groups. For example, geophagy had a prevalence of 55% among an antenatal clinic population in Georgia[56] and 57% of women and 16% of children in an area of rural Mississippi[10]. Many of the descriptions of the practice are in case reports focusing on pathological consequences[45,57] and these are not helpful in determining its prevalence or its association with iron deficiency.

In summary, the practice of geophagy is common in areas where iron deficiency is prevalent, particularly among pregnant women. There is good evidence that certain soils consumed may interfere with the absorption of non-haem iron in food consumed about the same time as the soil. Therefore, it seems prudent that consideration of the geophagy be included in the planning process of any interventions to reduce iron deficiency in pregnant women. The information needed to make appropriate decisions regarding the practice include: (i) the prevalence of the practice in target groups; (ii) the amount of soil consumed; (iii) the timing of the soil consumption in relation to meals; and, if these three indicate potential for interference with iron absoption, (iv) the chemical nature of the soils consumed.

Conclusions

There is substantial evidence that contaminant iron from soil and dust contributes significantly to iron intake in

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developing countries, but it is not clear how much of this joins the common pool (i.e. is exchangeable) to become available for absorption. Exchangeable contaminant iron is absorbed and its absorption is affected in the same way by dietary constituents as other non-haem iron in this pool. Determining the exchangeability of the various forms of contaminating iron is thus central to evaluating its likely impact on iron status.

This review found only one study that quantified the exchangeability of contaminant iron separately from other non-haem iron in foods. The results of this study indicated a wide range of exchangeability of iron in samples of soils (0–35%) and in iron-contaminated foods (3–35%). Contaminating iron that exchanges at the higher end of this range could have a substantial impact on iron status given the amount of contaminant iron in the diets of many populations in developing countries. Another study has demonstrated that the absorption of ferric hydroxide prepared in a laboratory was increased by the presence of ascorbic acid. The results of several other studies evaluating the exchangeability and/or absorption of total non-haem iron in meals contaminated with iron (i.e. intrinsic and contaminant iron together) confirm that contaminant iron has the potential to impact positively on iron status. However, no simple method for predicting the exchangeability of contaminating iron has been found and this severely limits the extent to which the impact of contaminating iron on iron status can be judged in any particular situation.

Some have argued that the iron leaching into food during cooking in iron utensils is better absorbed than the iron in soil and dust that contaminates food. Although this review has not found evidence to support this conclusion, the approach may provide an additional means of improving iron status. However, the efficacy of this approach will remain uncertain until the exchangeability of this form of contaminant iron can be predicted. It is recommended that additional studies are needed to determine the exchangeability of contaminant iron. The recent report from Ethiopia that eating food cooked in iron pots improved both haemoglobin levels and growth in the study population, suggests this approach has real potential. Interventions known to increase the absorption of intrinsic iron will also increase absorption of any contaminant iron that has joined the pool.

The practice of geophagy has the potential to adversely affect iron status if certain soils are eaten with foods, but in most circumstances the practice is probably not important to iron status. Any positive effect of geophagy resulting from an increased intake of iron is highly unlikely given its poor absorption. The public health impact of the practice on iron status will be determined by its prevalence, the amount of soil or clay consumed, the timing of consumption in relation to meals, and the chemistry of the iron consumed.

Conclusions resulting from all the above suggest that the focus of dietary interventions to improve iron status be on increasing the bioavailability of all non-haem iron, including contaminant iron, already present in diets. It is likely that the current trend of increasing iron consumption through fortification will become a more important source of dietary iron[58].

Further research should be undertaken to determine the exchangeability of the various forms of contaminant iron, with priority on the form that leaches into food during cooking in iron cookware. Information on the practice of geophagy should be collected as an integral part of developing any iron-intervention programme targeting pregnant women. The authors believe it is premature to promote the use of iron cookware as the primary basis of intervention ahead of other approaches to improve iron status until firm evidence of the efficacy of this approach is established. However, it may well be a useful adjunct to the prevention and control of this most difficult nutrition problem in public health. Public health nutrition interventions should be drawn from the whole range of available interventions and be applied in the most cost-effective and sustainable manner possible.

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