Science of the Total Environment 500–501 (2014) 199–210

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Evaluating environmental and social influences on iron and zinc status of pregnant subsistence farmers in two geographically contrasting regions of Southern Malawi

N. Dickinson [a,b], J. Rankin [b], M. Pollard [b], K. Maleta [c], C. Robertson [d], A. Hursthouse [a,*]

[a] Institute of Biomedical & Environmental Health Research, School of Science, University of the West of Scotland, Paisley PA1 2BE, UK
[b] School of Health, Nursing & Midwifery, University of the West of Scotland, Paisley PA1 2BE, UK
[c] University of Malawi, College of Medicine, Community Health, P/Bag 360 Chichiri, Blantyre 3, Malawi
[d] Department of Mathematics and Statistics, University of Strathclyde, 26 Richmond Street, Glasgow G1 1XH, UK

HIGHLIGHTS

- Soil iron higher in plateau than floodplain region. Soil zinc low in both areas.
- Maize iron and zinc not deficient relative to improved cultivars.
- Blood iron deficiency and anaemia prevalent in both areas. Zinc less problematic.
- Diet, comorbidities and social landscape may explain differing anaemia prevalence.
- Trends in nutrient status not accounted for by simple soil-plant-human transfer.

GRAPHICAL ABSTRACT

ARTICLE INFO

Article history:
Received 5 June 2014
Received in revised form 22 August 2014
Accepted 25 August 2014
Available online xxxx

Editor: F. Riget

Keywords:
Interdisciplinary
Malawi
Micronutrients
Soil
Maize
Blood

ABSTRACT

Micronutrient deficiency affects over 4.5 billion people worldwide, the majority in developing countries. Deficiencies of iron (and associated anaemia) and zinc in pregnancy are associated with complications, maternal and neonatal mortality, and developmental disorders in the foetus and growing child. We report the results of pilot study which used an interdisciplinary approach to explore environmental and sociocultural factors influencing the micronutrient status in the soil–plant–human transfer for pregnant subsistence farmers in two geographically contrasting regions of Southern Malawi. It evaluated micronutrient status in soil and the staple crop and explored the context for their transfer to pregnant women. Scientific and social science methods were used to collect data, following full sensitisation of the communities. A total of 99 participants were recruited from Chiradzulu (plateau) and Chikwawa (floodplain). Soil, maize and blood samples were collected, along with food frequency and health behaviour questionnaires and anthropological observation.
Statistical analysis revealed that soil iron was significantly higher in Chiradzulu than in Chikwawa; total iron concentration is not deemed to be deficient in either area. Soil zinc was not significantly different between areas. Maize concentrations of iron and zinc were not significantly different between areas, and were not deficient relative to improved cultivars. Blood iron deficiency and associated anaemia were problematic in both areas, but

* Corresponding author at: School of Science, University of the West of Scotland, Paisley, PA1 2BE Scotland, UK.
E-mail address: Andrew.hursthouse@uws.ac.uk (A. Hursthouse).

http://dx.doi.org/10.1016/j.scitotenv.2014.08.087

more so in Chikwawa than in Chiradzulu, and zinc deficiency was similar in both areas. The study has identified a significant difference in the blood iron status of the participants of the two communities, and has shown that this difference is not accounted for by the staple crop maize. Socio-geographical factors appear to play a significant role in the micronutrient health of the populations. The findings lend support to multifaceted community intervention studies which educate communities on strategies to tackle micronutrient deficiencies.

1. Introduction

It has been suggested that 4.5 billion people worldwide are affected by deficiencies of iron, vitamin A and iodine (Underwood, 2003), with zinc of increasing concern (Gibson, 2006). Pregnant women and young children are most vulnerable to these deficiencies (Steyn and Herselman, 2005; van den Broek, 2003; Cakmak, 2002). In addition to causing complications in pregnancy, micronutrient malnutrition diminishes motivation and development of children, consequently impairing mental and cognitive abilities. These children, deprived of their full potential for mental and physical development, become adults with lower intellectual and physical abilities (Graham and Welch, 2000). This has a knock-on effect on adult health and therefore economic development of societies in lower income countries (Black et al., 2008; The World Bank, 2006), locking communities into a vicious circle of poverty and malnutrition (UNICEF, 2007). Understanding and improving nutrition are critical to achieving most of the UN's Millennium Development Goals (United Nations, 2010): eradicating poverty and hunger, reducing child mortality, improving maternal health, combating disease, empowering women and achieving universal primary education (The World Bank, 2006).

It is widely reported that deficiencies of micronutrients exist in soil and crops, resulting in malnutrition of the population, particularly in subsistence farming communities where cereal-based diets have little nutrient diversity. In Malawi, Southern Africa, where maize is the staple crop, micronutrient deficiency has been recognised as a national health problem by the Malawian government (National Statistical Office of Malawi, 2004) and by international researchers (Ferguson et al., 1993b; Gibson et al., 2003; Yeudall et al., 2002). Of these, iron and zinc deficiencies have been recognised as particularly problematic in the Malawian population (Brabin et al., 2004; Gibson et al., 2003) and pregnant women specifically (Gibson and Huddle, 1998; van den Broek and Letsky, 2000). Iron deficiency anaemia (IDA) is one of the most significant factors in the high rate of maternal mortality (675 maternal deaths per 100,000 live births in Malawi, (National Statistical Office of Malawi, 2010)), and zinc deficiency compromises the immune system, thus contributing to the risk to mother and child (World Health Organization, 2007). Despite acknowledgement of widespread deficiencies of iron and zinc in African soils, there is little locally-specific soil data and little previous research studying soil–crop–health status (Steyn and Herselman, 2005; van der Waals and Laker, 2008; Yang et al., 2007). A review of iron and zinc transfer through the food chain and factors affecting this is available (Dickinson et al., 2009b) which emphasises the limited bioconcentration pathway for cereal crops. Other food groups and confounding factors may have more influence on nutritional status, but as the staple food, maize is worthy of investigation.

The persistence of nutritional deficiencies in developing economies requires wider consideration (World Health Organization, 2007; World Health Organization and Food and Agricultural Organization of the United Nations, 2004). What is the significance of the contribution of soil, via the staple crop, to human micronutrient deficiency? Stimulated by a UK Environment & Human Health research consortium programme (NERC, 2011) emphasising an interdisciplinary approach to investigate this issue. We report on an exploration of the links between the components of the food chain in two contrasting geographical regions of Malawi, incorporating an evaluation of socio-cultural factors on human health in relation to the environment. This food chain was used as a framework in this pilot project to study the environment and populations (Dickinson et al., 2009a), providing a "place" specific focus, informed by physical and social science approaches, deviating from traditional survey based on analysis common in both research domains. The approach included contributions from an environmental geochemist, epidemiologist, public health nurse, obstetrician, social scientist, midwives, anthropologist, and an interdisciplinary researcher. The complex interrelationships between humans and the environment in micronutrient cycling are outlined in Fig. 1; based on a conventional micronutrient food pathway, the conceptual model formed the basis of an interdisciplinary exploration of the agricultural, dietary, associated health and social factors relating to iron and zinc deficiencies. The study aimed to utilise a holistic approach to maternal nutritional health to provide new insights into the underlying geographical context. The study design and data collection were limited to key indicators for each main component, given the time and resource availability.

2. Materials and methods

A mixed methods approach was utilised (Creswell and Plano Clark, 2011), combining scientific measurement of soil, crop and blood total element concentrations with questionnaires and observational data to develop understanding of the relationships between the environment, food supply and human health.

2.1. Study area and sampling sites

Malawi is a land-locked country in Sub-Saharan Africa, bordered by Tanzania, Zambia and Mozambique (Fig. 2). The climate of Malawi is sub-tropical, relatively dry, and strongly seasonal. Two study areas were purposely selected to allow for a comparison of the micronutrient transfer chain between differing geographical locations. In order to achieve a maximum environmental contrast, a plateau and a valley region were chosen, both approximately one hour's drive from the city of Blantyre in Southern Malawi. The Shire Highlands is a plateau region to the east of the Shire River, a relatively densely populated agricultural area. Within the plateau is Chiradzulu district, at an elevation of 900–1100 m. The area experiences relatively cool temperatures (annual average 21.1 °C) and regional average annual rainfall of 800–1000 mm, making it ideal for arable agriculture (Scotland Malawi Partnership, 2007). The sample villages were within a ten minute walk of the main road. Chikwawa district is in the low-lying Shire Valley. At an elevation of approximately 100 m, temperatures are high (average 25.8 °C), and Chikwawa district receives amongst the lowest levels of rainfall in the country (<800 mm), although the area floods annually (Weatherbase, 2014). Chikwawa is one of the most problematic areas in the country in terms of food security (United Nations, 2011). The clusters of villages sampled here were very remote, being a thirty minute drive from the main road trading centre, along a dirt track which becomes inaccessible during the rains.

2.2. Field data collection

Ethical approval for the study was gained from the University of the West of Scotland Ethics Committee and the University of Malawi, College of Medicine (CoM) Research Ethics Committee. Prior to commencing fieldwork, an extensive programme of permission-gaining and community sensitisation was required; details are described in Dickinson et al. (2009a). A target sample of 50 women per area