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Cover picture: Tantalite small-scale mining in Nigeria
Kevin D'Souza, © Wardell Armstrong

Editorial

This issue of Earthworks focuses on two main themes: small-scale mining (SSM) and food-related issues in developing countries. All articles relate to studies undertaken under DFID's Knowledge & Research (KaR) Programme.

Two important articles are presented on SSM. Both draw attention to the extreme poverty existing in this sector and attempt to develop approaches to remedy this. In the first of these studies, Dr Mike Styles of BGS presents the results of a project aimed at improving practices in the small-scale gold mining sector. The work demonstrates how simple but appropriate local technology can dramatically increase gold recovery while at the same time benefiting the environment. The second account, from Kevin D'Souza of Wardell Armstrong, describes a more general analysis undertaken of the SSM sector, designed to develop a model scheme to assist small-scale miners. This stresses the range of factors that need to be addressed if policies are to be successful and sustained. Interestingly, both studies conclude that an effective way to induce change is to demonstrate the benefits of new techniques through pilot schemes as an example for others to follow.

The remaining articles relate to food and health. Two of these are concerned with improving the productivity of farmland through the use of locally available soil supplements. Dr Don Appleton of BGS describes how local phosphate rock can be used as a fertiliser in nutrient-poor tropical soils depleted by erosion and leaching. In a companion account, Clive Mitchell also from BGS describes how agricultural lime from local deposits can be used to neutralise the effects of acidified soils.

Finally, Dr Chris Johnson (BGS) reports on solutions aimed at increasing the availability of iodine in the local environment. His study is an attempt to document the behaviour of iodine in the natural environment as a basis for considering sustainable alternatives to the iodinisation of table salt.

Recovering the lost gold of the developing world

Mike Styles, British Geological Survey, Project R7120

Small-scale and artisanal gold mining is a vital source of livelihood for millions of poor people in developing countries. The efficiency of gold recovery in small-scale mining (SSM) is notoriously poor (reputedly around 30–40%), as evidenced by the fact that tailings are reworked many times. This project is aimed at improving gold recovery and encouraging more environmentally friendly methods, thereby achieving a more sustainable livelihood and a safer and cleaner environment for the miners and the local communities. The project has been carried out in partnership with the Geology and Mines Commission in Guyana, and ITDG in the UK and Zimbabwe.

Small-scale gold mining is difficult to precisely define but covers a range of activities from small groups of miners with limited finance and equipment to the hapless artisan trying to make a living with whatever comes to hand. The countries selected for this study, Guyana and Zimbabwe, span the range but this article focuses on Guyana. The first part of the project was a review and feasibility phase that included desk and field surveys, and covered both technical and sociological factors.

The technical review found that although many techniques are used for gold recovery in large gold mines, few are really suitable for SSM. Sluicing, which is already widely used, can be relatively efficient but only where the gold grains are not too small. However, it is very difficult to obtain information on grain-size distribution of gold in mining areas, and testing has to be a vital factor before recommendations on mining techniques can be made. In Guyana, for example, it was widely perceived that much of the gold was fine-grained and that loss of this was the main cause of poor recovery. However, a range of tests carried out on the alluvial gravel ore, the sluice box concentrates and the sluice box tailings showed that: (1) there was very little very fine-grained gold in the ore (always less than 10%) and (2) losses were across the spectrum of grain sizes but involved coarse gold in many cases. The perceived problem with fine-grained gold was, in fact, a groundless rumour: a well set-up sluice box with a more efficient gold-trapping mechanism should be able to recover perhaps 80% of the gold. Ironically, their boxes were quite good at trapping the finer gold, but unfortunately perhaps there was very little of it present in this instance.

Mike Styles, BGS © NERC

Typical sluice box with large rifles and black cocoa mats.

The surveys identified that miners' knowledge came mainly from copying their employers or neighbours but few really knew why they did it in a particular way or had any understanding of the basic principles of mineral processing. To improve recoveries, technology needed to be changed. The surveys also concluded that the best way to transfer improved technology to the miners was to carry out demonstrations and refit sluice boxes with better equipment. At the same time, staff from the Mines Commission were trained in ore testing and sluice box assessments, means of improvement, and giving advice to miners. Teaching materials for the mines officers to supplement their knowledge and enable them to carry out sustained assistance to miners, were also prepared.

By chance, a Canadian environmental project was also giving assistance to gold miners, and the projects agreed to collaborate. The initial joint demonstration was carried out in the Mahdia area in 1998. The recommended method of improvement was to install a Canadian-devised system of gold trapping. This

Mike Styles, BGS © NERC

Large sluices in Guyana.

involved replacing the traditional black cocoa mats, sometimes with large Hungarian riffles, that were in almost universal use, with vinyl 'Nomad' mats and shallower, expanded metal riffles. The width and slope of the box was adjusted to give optimum flow conditions. At that time these mats and riffles were very difficult to obtain in Guyana and had to be specially imported. The first refit was on the sluice box of one of the best-known and most well-organised miners, on the assumption that other miners were more likely to copy a local role model. Tests by Randy Clarkson, the Canadian mining engineer involved, showed that efficiency increased from around 60% (surprisingly high) to around 80% as a result of refitting.

A survey of the take-up of technology, along with further demonstrations, was carried out in 2001 in the Konawaruk area, some 50 km from Mahdia. This showed that of the miners that had been working in the Mahdia area in 1998, perhaps 100 groups, the majority had now moved to other areas. However, those that remained and many in the Konawaruk area, were mostly using the improved technology, to a greater or lesser extent. Most surprising was the fact that the better materials were now widely available locally and could be purchased over the counter at a small mining store in the interior. Many miners had made the capital outlay but not got the details quite right, which shows the need for follow-up instruction and on-going advice from mines officers.

The financial benefits were even greater than initially expected: the pay-back period as a result of improved gold recovery was estimated to be as little as two weeks to perhaps one month. The pile of the black mats wears away very quickly, which partly accounts for their poor performance and they have to be replaced every month or so. By contrast, the vinyl mats, although costing twice as much, wear much more slowly and those fitted in 1998 were still in use 16 months later.

This project found that there is less resistance to change than might be expected, and that miners will adopt new techniques provided they are appropriate and affordable. Convince a few and the rest will copy. In Guyana, the perceived best way to carry out gold sluicing has changed in two years due to the influence of technical assistance projects. The main environmental benefits are less reworking of tailings and damage to the local environs. Better gold-trapping means there is no need to use mercury in the pits and sluice boxes, as a good mat does the job efficiently. However, it is very difficult to persuade them not to use mercury or use retorts at the stage where they clean up the concentrate of gold and heavy minerals recovered on the sluice box. To the miners, speed of recovery and transparency, so that the whole team of miners can see what is happening, are far more important than possible long-term health dangers.

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Current projects

R7116, G1 Evaluating possible uses of Zimbabwean phosphate based wastes. (Ottos Ruskulis, Intermediate Technology)

R7120, G1 Recovering the lost gold of the developing world. (Mike Styles, British Geological Survey)

R7181, G1 Design and pilot implementation of a model scheme of assistance to small-scale miners. (Jeffrey Smith, Wardell Armstrong)

R7354, G1 Mercury-free coal-gold agglomeration (CGA) process for gold. (Professor Michael Mingos, Imperial College of Science Technology and Medicine)

R7370, G1 Local phosphate resources for sustainable agriculture. (Don Appleton, British Geological Survey)

R7410, G1 Low-cost lime for small-scale farming (FARMLIME). (Clive Mitchell, British Geological Survey)

R7416, G1 Sustaining communities through mine waste reclamation. (David Harrison, British Geological Survey)

R7118, G2 Cost-effective evaluation of hazards from mine waste. (Ben Klinck, British Geological Survey)

R7411, G2 Environmental controls in iodine deficiency disorders. (Chris Johnson, British Geological Survey)

R7815, G2 Landslide risk assessment in the rural access sector. (Gareth Hearn, Scott, Wilson Kirkpatrick & Co Ltd)

R7198, G5 Appropriate technology for low-cost geological mapping. (Eugene O'Connor, British Geological Survey)

R7199, G5 Strategies and systems for maximising geoscience data value. (John Laxton, British Geological Survey)

R7816, G5 Glacial hazard risk minimisation in rural environments. (John Reynolds, Reynolds Geo-Sciences Ltd)

R8035, G5 Self-help toolkit to construct a geo-science metadata system. (John Laxton, British Geological Survey)

R8036, G2 Socially sustainable development strategy. (Stephen Davis, Congo-Online Ltd)

KaR website

For more information on KaR geoscience projects visit www.bgs.ac.uk/dfid-kar–geoscience

A model scheme of assistance to small-scale miners

Kevin D'Souza, Senior Mining Engineer, Wardell Armstrong, Project R7181

Much has been written about the harmful effects of small-scale mining (SSM) on communities and the environment. Of the various factors associated with SSM, the one common denominator is the abject poverty of the sector. It should be remembered that many individuals only operate in this sector because they have no other choice. It is also true that many of the social and environmental consequences (e.g. child labour, lack of education, sub-standard sanitation, deforestation, river silting, mercury pollution, etc.) come about, not through deliberate, malicious intent but rather out of ignorance and lack of financial resources.

Wardell Armstrong (incorporating CSMA Consultants), in conjunction with the BGS, was commissioned by DFID to carry out an analysis of the global SSM sector aimed at developing a model scheme of assistance that could be implemented by central authorities and multilateral donors. A new approach is needed if the desperate poverty that exists within the SSM community worldwide is to be combated. The end purpose is to improve the quality of life of miners and communities by advancing structured policies aimed at the sustainable development of the sector.

A number of components make up a successful SSM project, all of which must be in place if SSM is to contribute real benefits to the miners, the local population, and the national government. The focus of any reform should be to provide financial empowerment to small-scale miners that will then act as a catalyst to other miners to improve their financial position. The best inducement to act within the legal structure, with due regard to health, safety and the environment, is to see other miners who have benefited financially from working within the legislation and have been aided by the government to do so.

The approach therefore should be all-encompassing, dealing with each of the relevant issues that are fundamental to the sector. An integrated approach should give the organisational and legal aspects, management techniques, and environmental and social issues at least the same priority as technical issues or the supply of equipment. An assistance programme that seeks to solve one aspect but ignores the others, while perhaps well-intentioned, is unlikely to have any lasting impact. Above all, if there exists a genuine desire to draw the SSM sector into the formal business community, there must be an acceptance that financial empowerment and gain is part of the process. The aim should be to encourage the miners to be entrepreneurs, not to constrain and hinder them. Although assistance programmes should be essentially non-discriminatory, there may be a rationale for trying to identify a small group of miners to aid initially in order that they can be used as an example for others to follow. This approach might be appropriate in concentrating limited resources on a key objective to avoid them being spread too thinly over a wide area, thereby achieving little.

Kevin D'Souza © Wardell Armstrong

Diamond mining in Ghana.

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Conclusions

The research identified a number of problems relating to SSM and the funding of aid programmes in this sector.

i The attitude of host governments to the sector varies considerably often due to reaction to recent events rather than the result of a rational development of strategy.

ii While a great deal of aid money is spent on the sector by donor agencies, the projects sponsored are usually aimed at specific topics and rarely address the sector as a whole and particularly the poverty issues.

iii Many of the projects that are funded are unsustainable in the long term in that they only last as long as there is aid money; once this is exhausted the projects cease.

iv The projects that are undertaken are often designed to control and regulate the sector. They are often studies rather than technical activities.

v There is widespread duplication of projects with little thought of budget-sharing or information-exchange. This has often resulted in poor utilisation of resources.

vi There appears to be a general reluctance, on the part of certain aid agencies to divulge information. This makes the determination of the success of projects extremely difficult.

vii There is little co-ordination between aid agencies, either on matters of funding or exchange of technical findings. Often, this appears to be because the aid agencies have their own specific agendas.

viii There are very few NGOs working in the sector, unlike other sectors such as agriculture. This means that there is little historical precedent.

One of the main findings of the project is that the problems traditionally associated with SSM occur as a direct result of the poverty associated with the sector. Often, the miners appear to have been effectively disen-

Kevin D'Souza © Wardell Armstrong

Gold mining in the Philipines.

franchised by governments and donors alike; the scale of the problem should not be underestimated. This scenario may be reversing as a result of the National Strategy for Sustainable Development (NSDD) policy that all countries have to target for by the year 2005.

Our initial report concludes that if governments and agencies wish to make a real difference to the situation, they must begin to address all the issues that affect the sector, not just the ones that are currently in vogue or politically correct. There needs to be a move towards a culture of wealth-generation and an attempt to draw the SSM sector into the legitimate social fabric of the country. Many of the present negative impacts of SSM could be mitigated by a concerted attempt to introduce these types of policies. Not only will they enhance the quality of life but they will also demonstrate the benefits of working within the legal framework rather than outside it.

The primary issues in this study fundamental to improving the general management, production, safety and environmental performances of the SSM sectors in the developing countries are:

Kevin D'Souza © Wardell Armstrong

Gold mining in the Philipines.

- defining a model government institution, unit or set-up to handle and/or manage the SSM sector
- establishing and enabling an appropriate legislative framework and licensing scheme for SSM operations
- defining relevant and consistent occupational health and safety standards and practices, and providing appropriate training on these issues
- establishing appropriate and realistic environmental protection principles and practices
- addressing the social welfare and gender issues that plague the sector
- delineating or defining the overall mineral potential for SSM exploitation, addressing the reliability and suitability of the deposit in terms of reserves and mineralogy
- establishing a self-sustaining technical assistance and training scheme for small-scale miners
- providing a viable and efficient financing and banking scheme for small-scale miners
- providing a simple and effective marketing system for SSM products.

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Low-cost lime for small-scale farming (FarmLime)

Clive Mitchell, British Geological Survey, Project R7410

The occurrence of acidified soils in many developing countries often leads to poor crop yields, a situation which could be easily remedied if agricultural lime (aglime) were used. However, subsistence farmers often fail to do so, in part due to lack of knowledge but also because aglime is too expensive. Production of low-cost aglime from suitable carbonate resources within farming districts would improve the access of small-scale farmers to this valuable additive. The aim of the FarmLime project therefore is twofold: first, to investigate low-cost means of producing aglime using appropriate local technology, and second to conduct crop trials to demonstrate its effectiveness.

Since the first report on FarmLime (Earthworks, November 1999), at which time the project had been running barely three months, a truly multidisciplinary team of collaborators has been established including agronomists, chemists, engineers, geologists and social scientists. The project activities are co-ordinated by the British Geological Survey (BGS) in conjunction with the staff of the Zambian Geological Survey Department (GSD) and the University of Zambia (UNZA) as follows:

- ***Project leader:*** Clive Mitchell (BGS)
- ***Socio-economic survey:*** Diana Banda (UNZA Department of Agricultural Economics) and Mlotha Damaseke (Programme Against Malnutrition, PAM)
- ***Carbonate resource assessment***: Boniface Muibeya and David Kapindula (GSD)
- ***Lime production research:*** Professor Stephen Simukanga (UNZA School of Mines) and Moffat Mwanza (UNZA Technology Development Advisory Unit, TDAU)
- ***Crop trials:*** Dr Victor Shitumbanuma (UNZA School of Agricultural Science)
- ***Project consultant:*** Briton Walker (UK).

Clive Mitchell, BGS © NERC

Hammer mill in action.

The socio-economic survey was intended to 'set the scene' in the farming districts by understanding the constraints affecting the use of aglime. At the same time, small-scale farmers willing to become involved in the crop trials element of the project needed to be identified. It quickly became apparent that the socio-economic and crop trials teams would benefit from working closely together. This study confirmed that small-scale farmers experience problems both in obtaining and affording aglime. Simple solutions to this were forthcoming from the farmers themselves: bulk buying of aglime by local co-operatives; making aglime available in smaller bags (25kg); substitution of part of their fertiliser for aglime; and bartering for aglime with maize or other products.

The carbonate resource assessment focused on dolomite deposits in Solwezi (North-Western Province) and Mkushi (Central Province), Zambia. Samples were collected on a simple grid pattern and evaluated in the laboratories of the GSD. Determinations were carried out for: neutralising value (NV) expressed as calcium carbonate equivalent (CCE); nutrient contents expressed as calcium and magnesium oxide contents; reactivity; and 'grindability'. As a result, the dolomite in both areas was found to be suitable for use as aglime. A private company has since set up an aglime production operation (HiQwalime) in Mkushi (although so far this mainly supplies commercial farmers).

The lime production study involved tests on bulk samples of dolomite from Mkushi using an adaptation of a hammer mill designed originally for maize milling. Initial field trials were carried out with the assistance of inmates from Munsakamba open prison (near Mkushi) who (with no irony) were set to breaking rocks to supply feed material for the mill! Based on these trials, a modified mill with strengthened hammers, additional wear plates and a smaller product screen has been taken back to Mkushi and Solwezi for final milling trials. The ground dolomite produced using the mill is used as aglime for the crop trials.

The crop trials involve small-scale farmers in the Mkushi area identified by the local agricultural extension officer as operating well-run farms and respected in the local community. The crop trials are situated in the Chalata and Kasansama agricultural camps, as well as the Mkushi Farm Training Centre.

Clive Mitchell, BGS © NERC

Carbonate resource assessment.

The trials include both maize, as it is a staple, and groundnuts, as they respond well to changes in soil acidity. The soil in these areas has a pH of 4.6 to 4.9 and therefore requires 200 to 450 kg of aglime per hectare for neutralisation of acidity. The crop trials use a conservation technique known as 'pot hole' farming (also referred to as 'precision farming') in which aglime or fertiliser are placed in regularly spaced holes rather than being spread over the entire area as in the more traditional 'ridge' farming. As only 7% of the farming land is used, the amount of inputs required is reduced. The method has been demonstrated to radically improve farmers' crop yields. Typical maize yield using ridge farming (without aglime) is less than 2 tonnes per hectare, whereas using 'pot hole' farming (with aglime) production has been reported at well over 10 tonnes per hectare, which exceeds the performance of even the large-scale commercial farmers! The crop trials will continue for five growing seasons to fully demonstrate the benefits of using aglime to small-scale farmers.

By spring 2002, the research phase of the project will be completed and the dissemination/demonstration phase will commence. FarmLime will be holding workshops throughout the SADC region starting with Lusaka in June 2002 and progressing to other countries, such as Kenya, Namibia, Malawi, Mozambique and Tanzania, over the next few years.

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Local phosphate resources for sustainable development

Don Appleton, British Geological Survey, Project R7370

A DFID overview of soil fertility issues in sub-Saharan Africa has highlighted the inherent low nutrient status of weathered tropical soils, as well as the loss of nutrients through erosion and leaching. Phosphorus is a key nutrient. Low soil-nutrient status can be rectified by increased inorganic fertiliser use. However, this is constrained by the lack of adequate knowledge regarding, amongst other things, the potential for the production of fertiliser materials from local phosphate rock resources, and non-industrial techniques for increasing the solubility of native phosphate rock. For forest/agriculture interface production systems, the application of a wide range of rock-based phosphate sources should be considered for dealing with the degradation of natural resources at the forest margin.

The various stakeholders concerned may not be adequately aware of locally available phosphate rock resources, nor their agronomic potential as a low-cost source of phosphate for the enhancement of soil fertility and productive capacity of relatively poor, smallholder farmers. A need therefore exists to ensure that the use and development of local resources is considered as an option for restoring the P-status and productive capacity of degraded soils. The DFID-funded KaR project Local Phosphate Resources for Sustainable Development will produce three regional reviews (covering sub-Saharan Africa, Asia, and Latin America) which will provide advisers with a concise summary of national and regional information on local phosphate resources.

The first section of the African report contains regional or generic reviews of:

- phosphate mineral resources of sub-Saharan Africa, including information on phosphate rock and phosphate fertiliser production, consumption, and export
- phosphate rock products and processing options
- estimated investment required for mining, infrastructure and processing options
- constraints for utilisation of phosphate rock resources
- environmental constraints related to heavy/hazardous elements contained in the rock phosphates or their by-products
- existing or anticipated direct use of phosphate rock in agriculture including general results of agronomic and economic assessments and
- the role of phosphate rock in strategies for dealing with soil fertility.

The second section of the report comprises thirty-one country profiles, each of which summarises:

- quantity, quality and location of local phosphate rock deposits/sources in each country (maps indicate the location of the phosphate resources and major transport routes)
- past and current phosphate rock production, including export as intermediate/raw materials and local use in agriculture and
- agronomic and agro-economic assessments of rock phosphates and associated phosphate fertiliser products, including information on the soil types and crops likely to show a positive response to direct application of rock phosphate fertilisers.

Phosphate rocks in sub-Saharan Africa are of two major types. (1) Sedimentary deposits of phosphate rock formed in coastal marine or lacustrine environments as the result of biogenic activity. These are predominant in western Africa. (2) Phosphate deposits associated with alkaline and carbonatite igneous complexes, mostly of Jurassic, Cretaceous and Tertiary age. Most of the phosphate deposits in southern and eastern Africa are of this type.

The distinction between sedimentary and igneous phosphate rocks may not be of major importance if these are beneficiated and used for manufacturing chemical fertilisers. However, the low reactivity of igneous phosphate rock generally makes it unsuitable for use as a direct-application fertiliser, other than in special circumstances such as tea plants grown on very acid soils in areas with high rainfall. Extensive lateritisation of phosphatic sedimentary rocks has produced aluminium phosphate deposits at a number of localities of which the most important is the Pallo deposit in Senegal. Relatively small deposits of bat and bird guano occur at a number of localities.

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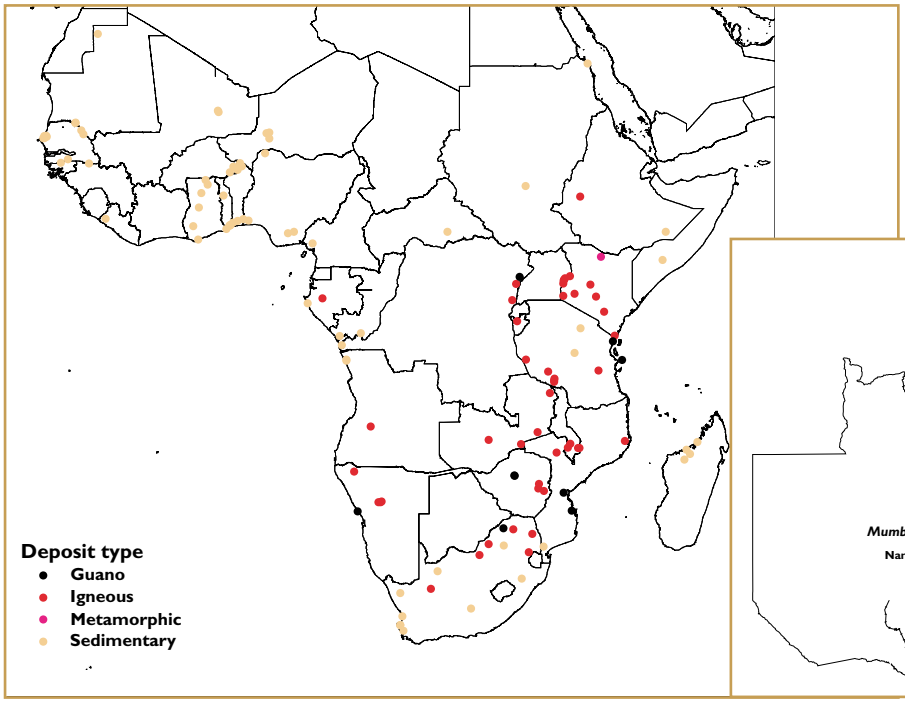
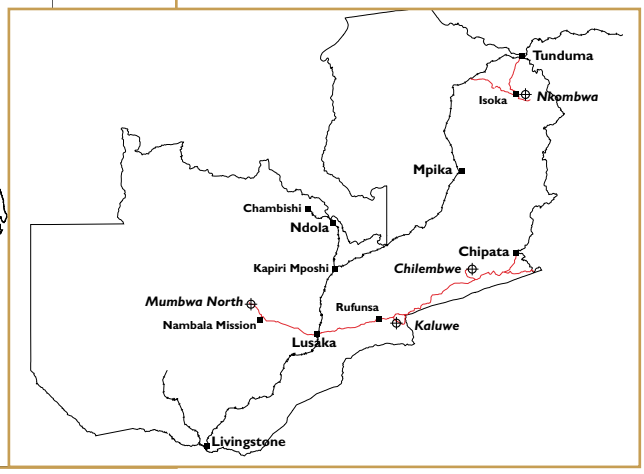


Location of phosphate deposits in sub-Saharan African.



Location of phosphate rock resources in Zambia.

Dr Alex Stewart, Wirral Health Authority

Soil sampling in Xinjiang province, China.

Environmental controls in iodine deficiency disorders (IDD)

Dr Chris Johnson, British Geological Survey, Project R7411

Iodine is an essential trace element for humans and animals. A deficiency of iodine in the diet will lead to iodine deficiency disorders (IDD), the most strikingly obvious manifestation of which is goitre — an enlargement of the thyroid gland in the neck. Infants born to severely iodine-deficient mothers may be mentally retarded (cretinism); indeed, iodine deficiency is reported to be the world's most common cause of mental retardation and brain damage. In developed countries and many parts of the third world, this problem has been tackled successfully using medical intervention techniques such as the iodinisation of table salt. However, such intervention requires continuous input to local communities from outside agencies and, moreover, is only successful where the local communities are prepared to accept the methods used. For example, very poor communities will often continue to use salt made from traditional sources simply because they cannot afford to buy table salt.

This current project is looking at environmental solutions to increase the availability of iodine in the local environment. During the past year, the project has collected samples of soil, water and foodstuffs from an iodine-deficient area of Xinjiang Province, China. Here, an American-sponsored project (Kiwanis International) has been adding iodine to the environment through dripping potassium iodate into irrigation waters. The ongoing study will provide information on how iodine migrates through the food chain to provide this essential trace element in our diet. Results to date suggest that, whilst the dripping programme results in a significant short-term increase in the iodine status of the local population, in the long term the added iodine does not appear to have a long residence time in the soil. This emphasises the need to establish which factors are responsible for fixing iodine in the environment and what agricultural practices best ensure that iodine gets transferred into crops.

A comprehensive database of iodine's behaviour in the environment is being prepared and will be available together with other information on the project's website.

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