HEAVY METAL CONTAMINATION OF VEGETABLES IN DELHI

Executive summary of technical report– March 2003

Dr Fiona Marshall, Ravi Agarwal, Dolf te Lintelo, Dr D S Bhupal, Dr Rana P B Singh, Dr Neela Mukherjee, Dr Chandra Sen, Dr Nigel Poole, Dr Madhoolika Agrawal, Dr S D Singh.

INTRODUCTION: This paper describes selected findings from an interdisciplinary research project funded by the UK Department for International Development (January 2000 to April 2003) which was carried out in Delhi and Varanasi by Imperial College, London in partnership with Srishti; Delhi University; Banaras Hindu University, Varanasi; Development Tracks, New Delhi and the Indian Agricultural Research Institute.

The aims of the research in Delhi were to:

- Measure the levels of heavy metal contamination of vegetables in Delhi markets
- Consider the sources of the heavy metals found in vegetables
- Assess how the heavy metal contamination might impact on local livelihoods
- Determine any simple technical interventions that could reduce heavy metal contamination
- Recommend interventions in terms of policies and programmes that could reduce heavy metal contamination
- Draw lessons for policy approaches to improve food safety in India

The data in this paper focuses on palak/spinach beet. Not only is palak recognised as a highly nutritious food, but also our research clearly shows that spinach is an extremely important crops in the peri-urban zone, is predominantly grown by small-scale farmers and is commonly consumed by the poor.

BACKGROUND: The importance of consumption of fresh vegetables for the urban poor.

Urban food security in India is a matter of growing concern. It is estimated that by 2025, 60% of India's population will be living in urban areas, and an increasing proportion of city dwellers are poor. Urban poverty is reflected in the nutritional status of the urban poor, whose intake of important nutrients frequently lies below the minimum recommended daily allowance. Over the past few decades there has been a change in the focus of nutritional health concerns in India, from malnutrition, to widespread chronic shortages of micronutrients, particularly iron and vitamin A. Whilst these deficiencies are not directly life-threatening, they cause serious functional disorders (Gopalan, 1994a), and women and children are particularly vulnerable.

In this context it is particularly important to encourage the consumption of highly nutritious fruit and vegetable (F&V) crops, but as the income elasticity of demand for these products tends to be high, there is a clear need to increase supply and maximise the nutritional quality of these products to benefit the poor. This is also acknowledged

by the Government of India's policy, which recognises the long-term preventative need for sustained increased consumption of fresh vegetables and fruits, rather than distribution of iron and vitamin supplements. Our studies have shown that awareness is slowly increasing about the nutritional benefits of consuming vegetables, and of Palak in particular. Participatory research studied villages in the fringe areas of Delhi were aware that spinach was good for health and expecting mothers must consume it for healthy growth of the foetus.

Whilst support for increased production and consumption of fresh vegetables is an important goal, citizens have a right to safe food and to be ensured that the vegetables available to them are not contaminated beyond acceptable safe limits.

Chemical contamination from sources such as industries, vehicles and pesticides can affect the safety of food. Heavy metals are one of a range of important types of contaminants that can be found on the surface and in the tissue of fresh vegetables. Prolonged human consumption of unsafe concentrations of heavy metals in foodstuffs may lead to the disruption of numerous biological and biochemical processes in the human body. Heavy metal accumulation gives rise to toxic concentrations in the body, while some elements (e.g. arsenic, cadmium, chromium) act as carcinogens and others (e.g. mercury and lead) are associated with developmental abnormalities in children.

Vegetable crops are often grown in polluted and degraded environmental conditions in the peri-urban (or urban fringe) zone and are subject to further pollution from vehicles and industries during marketing. There is therefore significant cause for concern regarding contamination.

Highly perishable vegetables such as palak are predominantly grown in the urban fringe area. Whilst within Delhi (National Capital Territory) there are important but diminishing agricultural areas, also immediately beyond the administrative boundaries areas. Vegetable cultivation is popular. Our research has shown that villages in and around Delhi NCT use an average of 9% of agricultural land for the cultivation of vegetables, with some using up to 35% of the land for growing these crops. An important factor affecting both land use and cropping patterns is the access to transport networks for linkages with urban markets for agricultural produce, labour and capital. Previous research by Imperial College London and Delhi University research teams have shown that in Delhi approximately 72% of palak traded in Azadpur wholesale market in Delhi is grown within Delhi NCT.

Our research also provided clear evidence of the fact that vegetable production also has a major role to play in supporting the livelihoods of the poor. These people often have little choice but to farm in polluted areas, and have limited access to advice and support.

Vegetable farming in Delhi is mainly conducted by farmers with low socio-economic status cultivating small or marginal landholdings. Smallholder farmers have a preference for growing palak and all family members that is women, children and men contribute. In addition, the poorest groups of agricultural wage labourers work on vegetable farms. This type of vegetable cultivation hence supports livelihoods primarily through food provision, income generation and employment.

HEAVY CONTAMINATION OF VEGETABLE SAMPLES FROM DELHI MARKETS: THE EVIDENCE

Sampling strategy

MARKETS: From May 2001 to Feb 2003 fresh vegetable samples (gobhi/cauliflower, bhindi/okra, palak/spinach beet) were collected from five broad sampling areas in Delhi (Faridabad, Okhla, the Yamuna flood plain, Najafgarh & Alipur), to assess the heavy metal contamination of vegetable currently being purchased in Delhi markets. Five sampling sites were selected in each of the five broad areas, and at each sampling site 3 replicates samples were collected from different retailers and vendors. An additional 15 samples were collected from Azadpur wholesale market in each sampling occasion. This amounted to 90 samples per crop per month (For palak each replicate sample consisted of 0.5 kg of fully expanded leaves; for okra 0.5 kg of fully mature okra). The sampling periods were April and May (palak); July-August (palak and okra), December-January (cauliflower, palak)

Samples were also taken from a wide range of field production sites in and around the cities, the most important vegetable production areas were identified on the basis of field surveys carried out by our research team.

Analysis of heavy metal content

Standardised International protocols were followed for the preparation of material and analysis of heavy metal content.

The samples were immediately oven dried at 80^{o}C until fully dry and were then ground to a fine powder. Samples were then digested using a tri-acid digestion process to extract the heavy metals, and the resulting solutions analysed for concentrations of Lead (Pb), Copper (Cu), Zinc (Zn) and Cadmium (Cd) with the highly sensitive ICP-MS (Inductively coupled plasma mass spectrophotometer).

A number of other techniques are also being tested using analysis equipment that is more readily available in Indian laboratories.

Quality control of samples

It is important to be aware of the fact that the measurement of heavy metal concentrations is fraught with a number of difficulties. Different values are often obtained with the same samples tested at various laboratories. The influencing factors include the precise digestion methodology used, the sensitivity of the heavy metal detection instrument, the potential for contamination of samples and the potential for interference from other chemicals when assessing the levels of certain heavy metals.

Great care was taken to assure the reliability of data being presented here (a much larger data set may be available once quality control processes are complete). Internationally certified plant standard reference material (SRM) is an important tool for the quality control process. This material has known concentrations of the heavy metals that we are concerned with, and can therefore be used to test the reliability of findings from a range of laboratories.

LEVELS OF CONTAMINATION RECORDED

For Delhi, the research indicates that:

- *Consumers are purchasing vegetables with high levels of heavy metals (HMs)*
- *Legally permissible limits as defined by the Indian Prevention of Food Adulteration Act, 1954 are regularly crossed, whilst these norms are less strict than international food safety norms like Codex Alimentarius or European Union standards.*
- *However, there is no regular testing of heavy metals in vegetables by the designated authorities in India*

1. Lead

The main cause for concern in terms of contamination of vegetables in Delhi by heavy metals relates to Lead (Pb). 72 % of 222 (quality controlled) samples of palak contained Pb concentrations that exceeded the Indian (Prevention of Food Adulteration act (PFA) permissible limit of 2.5 mg/kg. If the more stringent CODEX limit of 0.3 mg/kg is used, then 100% of the palak samples exceeded safe limits. 24 % of the samples exceeded the PFA permissible limit by more than 2 fold (i.e had concentrations of > 5.0mg/kg). 102 of these samples were taken during the peak winter season, and of this sub sample 43 % had concentrations of > 5.0mg/kg.

2. Zinc

21 % of 609 palak samples analysed showed Zn concentrations that exceeded Indian PFA limits (50 mg/kg). 3% had concentrations at twice the PFA limit. From the summer (257 samples) 25 % exceeded PFA limits, for the winter (230 samples) 18% and rainy season (122 samples) 17% exceeded. In this case there are no International standards that are more stringent than the Indian standards.

3. Cadmium

100 % of the 260 samples of palak had concentrations of Cd Within the PFA limits (1.5 mg/kg), but 70% exceeded the much more stringent EU standard (0.2 mg/kg)

4. Copper

The copper levels found in Palak were within safe limits in all samples.

Sources of Heavy Metal contamination

Heavy metal depositions are associated with a wide range of sources such as small-scale industries (including battery production, metal products, metal smelting & Cable coating industries); brick kilns; vehicular emissions; re-suspended road dust and diesel generator sets. These can all be important contributors to the contamination found in vegetables. In general, coal combustion is an important source, because Indian coal is of relatively poor quality and has high heavy metal contents.

Additional potential sources of heavy metals in field locations in urban and peri-urban areas include irrigation water contaminated by sewage and industrial effluent leading to contaminated soils and vegetables. Other sources can include unsafe or excess application of (sometimes banned) pesticides, fungicides and fertilisers such as sewage sludge (Krishna Murti, 1989).

Heavy metals may be present as a deposit of the surface of the vegetable, or may be taken up by the crop roots and incorporated into the plant tissue. In either case the original source of the pollution may be from water borne sources (such as industrial effluent) or from industrial or vehicular air pollution. This distinction is very important, because metal deposited on the surface of the crop can often be washed off by consumers prior to consumption.

A proportion of the heavy metals in our palak samples were present on the surface of the crop, whilst the remainder may have been taken up via the plant roots into the edible portion of the crop. We have carried out some experiments where we have emulated washing practices in Delhi households. These have shown that, in the case of spinach that contamination is reduced by 20% after one wash in a tub of clean water, but after a second wash it is reduced by approximately 50%. A third wash does not appear to reduce the contamination further.

The pattern for zinc and cadmium is rather different. Washing of palak once, twice or three times does not appear to reduce the concentrations. This suggests that much of the zinc and cadmium may be present in the plant tissue.

More thorough experimental laboratory tests with detergent washings would be required to determine the precise proportion of the total contamination that was present on the surface of the vegetables, this is purely an experimental tool to quantify where the contamination is, and not a practical recommendation!

There is tremendous variability in the ability of crops to take up heavy metals through their roots and transport them to the edible portion of the plant. This depends, not only on the type of heavy metal but the also the species and cultivation of crop being grown and the prevailing soil and other growing conditions. Lead, e.g. is not readily taken up by many plants, and even if it is taken up by the plant roots it is often not transported to the edible portion of the plant. However, green leafy vegetable such as Indian mustard and spinach are known to take up heavy metals such as Lead.

Which members of the community are most affected by HM contamination?

The research highlights that poor urban consumers (defined as those households with monthly incomes of less than 3000 rupees) could be affected more by the heavy metals present in vegetables purchased for the following reasons:

- poor consumers wash their vegetables less thoroughly than better off consumers
- the poor may purchase vegetables that have been in the market for a longer time at a lower price, therewith increasing the risk of longer exposure times of the vegetable to aerial deposition of heavy metals
- the poor have less access to higher priced food that is perceived to be of higher quality

- the poor may be more susceptible to the adverse effects of HMs due to an already unfavourable relative health and nutritional situation, with particular reference to women and children
- Our consumer studies indicate that awareness of food safety issues is lower amongst lower income groups

On the other hand, wealthy consumers may be more exposed to HMs through greater overall consumption of vegetables. The wealthy are able to purchase costly 'off season' vegetables when high doses of agro-chemicals (some containing heavy metals) are applied by farmers to stave off insect pests.

What is the potential to reduce crop contamination and improve safe food?

➔ **Reducing pollution at source**

Reduced industrial and vehicular pollution of water, soil and air will prevent high concentrations of heavy metal traces such as cadmium and lead from entering the food chain.

Aerial deposition of heavy metals can be reduced by measures such as:
- Setting emission standards for HMs which account for contamination of food
- Monitoring of HMs in aerial deposition, stack emissions and industrial effluent.

Urban and industrial development planning processes, such as the currently formulated Masterplan of Delhi 2021, are required to take contamination of food supplies into account in industrial siting decisions. However, even if it were practical to site industries away from the immediate vicinity of agricultural areas this will not solve the problems associated with aerial emissions. This is because the heavy metals may be deposited at highly variable distances from the source of emissions, and thus, the pollution should be monitored and controlled at source. There is also potential to reduce the further accumulation of heavy metals in soils through monitoring and controlling heavy metal contamination that MAY be associated with use of wastewater for irrigation, sewage sludge and municipal compost and certain pesticides.

Currently there is no regular testing of heavy metals in vegetables by the designated health authorities. Thorough and transparent food testing inspections and dissemination of results by well-qualified government and non-government organisations are needed. Regular monitoring will also help to raise awareness about the food safety issue and will strengthen consumer demand for anti-pollution measures and better quality food for all.

➔ **Improved vegetable production and post harvest handling**

It is important to recognise that farming in areas close to cities performs a very important role in providing cities with fresh vegetables, and that small-scale farmers in particular, and agricultural labourers, derive a livelihood from this. It is also essential to encourage the intake of highly nutritious produce such as palak. However, farmers need to be made aware of best practices regarding the hazards associated with certain pesticides, fertilisers and irrigation water sources during cultivation. Also farmers often wash produce before bringing them to the market, and they must be encouraged to wash in clean water. Good coverage of vegetables during transport & sale may also help in reducing additional contamination post harvest.

In order to provide firm agricultural recommendations additional locally based field research studies may be required in Delhi to more fully understand the amount of heavy metal uptake of commonly grown crops and cultivars, in relation to the concentrations found in the local soils, irrigation water and in other external inputs.

➔ Using support for vegetable trading systems to improve food safety

Marketing studies carried out in this project aimed to understand the organisation of the vegetable marketing system from production to consumption, to assess the level of coordination, and to identify policy entry points for improving performance. Recommendations of mechanisms to improve the market system performance would be expected to operate through an appropriate mix of indirect and direct approaches, from the provision of information, through the creation of market incentives, to regulatory action.

Market organisation: structure and strategy

Peri-urban production of the three study crops is an important source of seasonal vegetable supply to all consumers in Delhi. Produce flows from farmers through complex market channels of intermediaries, who assume individual responsibility for the value-adding functions of transport, assembling, exchange, and distribution to final consumers. In the regulated market system such as in Azadpur, the commission agents are a nexus of control in arranging buyers and negotiating prices. There is little processing apart from operations such as trimming and 'freshening' of produce to improve appearance. Freshness is the primary quality factor in the pricing of the most perishable vegetables (e.g. palak).

There is little evidence of trust and 'client relationships' between the different buyers and sellers in the chain. There is little exchange of information, such as knowledge about production practices and consumer preferences. The price mechanism in the mass, wholesale market system has limited potential to align quality incentives between production and consumption.

Consumer behaviour

Consumers buy frequently during the week from permanent stalls, from retailers in local periodic markets, and from vendors. Clearly, higher income consumers have options not available to poorer sections of the population. Better-off consumers are able to exercise their preferences for high quality appearance, and for location by purchasing from enhanced retail outlets and vendors who visit at home. In addition, quality assurance is implicit through retail outlets such as Safal, and the INA market where value is added through reputation effects and added services such as packaging and delivery. The high quality retail outlets are supplied through short market channels and fewer middlemen. The ability to trace produce from such retail outlets to production is a characteristic of the sophisticated market segment that is not feasible in the mass segment flowing through the wholesale markets.

Summary

The study has found that flows of information and incentives through the mass market are limited by the focus on the price-appearance relationship. It is evident from the

consumer research that there is a positive relationship between income and education levels on the one hand, and awareness of food safety hazards on the other. That is to say, poor consumers who are more likely to be subject to environmental health hazards, are not only less able to pay a price premium, but are also less aware of the potential health hazards of food contamination.

The outcome of the study is that, with the limited information available to them, poorer consumers are unlikely to demand vegetables that are quality-assured in respect of food safety such as freedom from contaminants (be they heavy metals from air pollution, or from agrochemical or microbial sources). Moreover, the current mass assembly and distribution system through the wholesale markets is not able to convey signals about food quality other than freshness, nor mechanisms of quality assurance other than visual inspection of produce.

The study recognises market interventions with potential for improved food safety.

1 Producers

- In the long term, the market system is likely to evolve towards more direct systems with reduced linkages that may be more efficient and exhibit lower producer-consumer margins. In the short term, having limited choice in accessing markets disadvantages producers. Where produce has to pass through the control of commission agents in the wholesale markets, producers are price takers. Regulated markets such as Azadpur will continue to have a part to play in the national food system. However, Delhi may wish to embrace other types of market systems that operate elsewhere in the country, particularly where farmers have the opportunity to avoid the control of middlemen:
    - farmers' markets such as the 'apni mandies' in Haryana and Punjab
    - 'hadapsar mandies' near Pune;
    - 'ritubajar mandies' in Andhra Pradesh (Vishakapatnam)
- The intention of the Azadpur to set up two markets for organic products is an example how 'plural' market systems are likely to evolve, giving greater choice of outlet to producers.
- The evolution of markets is also likely to lead to a proliferation of premium quality systems such as Safal and the well-coordinated INA model.

2 The link between market infrastructure and market coordination

The government authorities at Central and State (Delhi city) level have the means to expedite the evolution of better-coordinated markets. Provision of facilities and implementation of economic fees structures payable by traders is likely to expedite the concentration and professionalisation of the food retailing function among dedicated firms, this is likely to lead to more efficient and better-coordinated markets. The 'casualisation' of food retailing is likely to reduce, not without negative consequences for the smallest retailers, but thereby, food safety standards are likely to rise.

3 Public awareness of food safety hazards

- Information to consumers, traders and producers: there is a need for more information and awareness of safety hazards, targeted not only to consumers but also to market intermediaries.
    - The middlemen can be reached through

- the secretaries of the Agricultural Produce Marketing Committees of the regulated markets such as Azadpur, which can develop forward and backward linkages in the chain to convey information flows to retailers and to producers;
- the National Institute of Agricultural Marketing (Jaipur)

➔ **Increased consumer awareness:**

Experimental programmes by the research team have highlighted that a simple, low cost opportunity for people to reduce HM contamination is by thorough washing of vegetables in clean water**. We have found that at least 50% of the Pb contamination on palak is found on the surface of the vegetables and by twice washing in clean water the Pb contamination can be reduced to within PFA safe limits**. In Delhi, generally heavy metal levels in municipal tap water are well within safe limits and exposing vegetables to this water does not pose an additional threat of contamination.

Clearly the potential to reduce HM contamination by thorough washing depends on the access that people have to clean water sources, and competing needs for this scarce commodity; this may be a barrier for some of the poorest communities. The capacity to reduce food contamination will be an added advantage of improved water supply and sanitation, which is already recognised as an important poverty alleviation tool.

Existing formula's for increasing awareness could be well applied to enhance awareness about simple food safety interventions. For instance, the Municipal Corporation of Delhi raises awareness about public health through advertised messages (in English & Hindi) in newspapers, cinema slides and hoardings on buses and at the roadside. The Government of Delhi also uses innovative awareness raising means such as short messages broadcast through the telephone.

➔ **Increased awareness amongst policy makers**

Consultations with a wide range of policy makers indicates that current awareness levels about HM contamination of vegetables amongst key policy agencies responsible for public health, pollution control, food safety inspection, horticulture and nutrition are low. In the absence of solid scientific data, many policy makers feel discouraged to act on heavy metal pollution. However, a clear demand for information about environmental pollution impacts on food safety exists and these project findings will support policy making in this respect. In India, the institutional capital exists to facilitate conveyance of simple food safety messages to policy makers and (poor) urban consumers. Partners who could assist in increasing awareness can include NGOs, schools and public and private sector organisations working on environment, health, nutrition etc

AN INTEGRATED APPROACH TO ENSURING FOOD SAFETY

The study is a pointer to the inefficacy of current approaches towards ensuring safety of food to the consumer. Clearly food contamination can take place at various stages of the food chain, and food safety needs to be ensured throughout for it to be safe for consumption. Starting from the cleaner production sites, to transport and marketing practices (both wholesale as well retail) and consumer practices, various interventions need to be made. Current policy relates to food standards, environmental standards,

industrial siting, peri-urban agriculture and consumer rights separately and is inadequate to tackle the issue comprehensively.

A fundamental change in policy approaches to food safety may be required which are based on prevention rather than command and control of food quality at the retail end of the food chain.
Such an preventative approach will also reduce the need and the cost for expensive inspection regimes, which are particularly difficult to implement with regard to fragmented small-scale food economies, like vegetable retailing.

High levels of contamination, such as this study shows, continue to go undetected, with little recourse for the consumer. Ensuring safe food needs the highest priority, and needs examination of the issue in an integrated manner.

Such integration can be incorporated through an empowered multi-stakeholder agency such as a 'food safety board,' for example, which has powers to examine the issue in all its aspects. Such approaches have also worked in other countries and have previously been proposed in India by Indian advisory committees. For instance, the 1998 Task Force to the Prime Minister's Office under Shri Nulsi Wadia have recommended setting up an integrated 'Food Regulatory Authority' to deal with all food safety issues, but currently no such body yet exists.

NOTE:
This publication is an output from a research project funded by the United Kingdom Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID. R7530 Crop Post Harvest Research Programme.