Institution: University of Aberdeen

Unit of Assessment: 6 - Agriculture, Veterinary and Food Science

Title of case study: Discovery of rice as the major dietary source of inorganic arsenic resulting in improved international public health policies, and clinical and dietary guidelines

1. Summary of the impact

Research by Professor Andrew Meharg at the University of Aberdeen was the first to show that rice constituted the major source of dietary exposure to inorganic arsenic, a class 1, non-threshold carcinogen, meaning that there is no dose that is risk-free. This research directly led to the European Food Safety Authority (EFSA) undertaking a major review of arsenic in foods. The EU, USA and WHO lack standards for arsenic in food, but all three are now actively seeking to set standards. Subsequent to the Aberdeen studies, the WHO withdrew its standard for arsenic Provisional Tolerable Daily Intake, considering it too high. Also, as a direct result of this work, the UK Food Standards Agency (FSA) has issued warnings that children under 4 should avoid rice milks because of their inorganic arsenic content.

Therefore claimed impacts are: affected health and welfare; enhanced awareness of health risks, altered dietary guidelines and changes to public and international policies and guidelines.

2. Underpinning research

The role of researchers at the University of Aberdeen in unravelling the importance of arsenic in rice began with a series of publications typified by Abedin et al. (2002) [1]. These identified that the irrigation of paddy rice with groundwater containing high levels of arsenic in Bangladesh and West Bengal, India, might be of concern, placing earlier physiological studies on arsenic assimilation by rice in context. This was shortly followed by the first field survey of arsenic in rice grain to be published anywhere, identifying that indeed there was extensive arsenic contamination of rice, and paddy soil, in Bangladesh [2]. Furthermore, this publication was the first to question the failure of international bodies to set clear arsenic standards, and, more specifically, the failure to account for and legislate against arsenic in foodstuffs.

These initial findings provided impetus for further study, resulting in the first paper to consider arsenic in rice in a global context. This study revealed that EU, USA and Bangladeshi arsenic levels in rice were elevated above “natural” levels, and was the first to identify that arsenic speciation (the identification of the chemical forms of arsenic present) in rice varied between different rice producing regions [3]). The findings for Bangladesh were further clarified by detailed rice grain surveys, culminating in the most detailed global assessment of total and inorganic arsenic content of rice grain to date [4]. This enabled cancer risks from arsenic-contaminated rice to be estimated on a regional basis, showing that there is an elevated risk of bladder and lung cancers from rice based on the most up to date US EPA modelling of inorganic arsenic cancer risks. Those risks are highest for countries such as Bangladesh that have very high rice consumption rates combined with highly arsenic-contaminated rice.

The realisation that rice consumption represented a major source of inorganic arsenic exposure led to the investigation of specific rice-based food products. This phase of arsenic in rice studies identified that inorganic arsenic in baby rice [5] and rice milk [6] were of considerable concern. These two papers led directly to the 2009 EFSA review of arsenic from foodstuffs [c] and the UK FSA report, also in 2009, advising that rice milk should not be given to children under 4 years old [a]. Highest inorganic arsenic levels were identified in stabilized rice bran products [7]. These products had been marketed as health supplements, and more worryingly, as nutritional supplements for aid programmes in developing countries. Rice bran is still used widely in rice products, particularly in the health-food market.

3. References to the research

[1] Abedin MJ, Cresser M, Meharg AA, Feldmann J & Cotter-Howells J. (2002). Arsenic accumulation and metabolism in rice (*Oryzasativa*). *Environmental Science & Technology* 36, 962-

968. WoK cited 220 times.

This is the first paper to mention that arsenic in rice could be problematic due to rice's physiology and agronomic practice in the Bengal Delta.

[2] Meharg AA & Rahman Md M. (2003). Arsenic contamination of Bangladesh paddy field soils: implications for rice contribution to arsenic consumption. *Environmental Science & Technology* 37, 229-234. WoK cited 307 times.

This paper represents the original body of work leading to the claimed impact. In this the levels of arsenic are explicitly measured in the field, and identified as problematic.

[3] Williams PN, Price AH, Raab A, Hossain SA, Feldmann J & Meharg AA. (2005). Variation in arsenic speciation and concentration in paddy rice related to dietary exposure. *Environmental Science & Technology* 39, 5531-5540. WoK cited 241 times.

*This paper was identified by Thompson Reuters Essential Science Indicators***,** *November 2009, Environment & Ecology category, with Williams et al. (2005) as the most cited paper in the Fast Moving Front 'Arsenic speciation'*. *http://sciencewatch.com/dr/fmf/2009/09novfmf/09novfmfMeha/.*

[4] Meharg AA, Williams PN, Adamako E, Lawgali YY, Deacon C, Villada A, Cambell RCJ, Sun GX, Zhu YG, Feldmann J, Raab A, Zhao FJ, Islam R, Hossain S, Yanai J. (2009). Geographical variation in total and inorganic arsenic content of polished (white) rice. *Environmental Science & Technology.* 43, 1612-1617. WoK cited 98 times.

[5] Meharg AA, Sun G, Williams PN, Adamako E, Deacon C, Zhu YG, Feldmann J, Raab A. (2008) Inorganic arsenic levels in baby rice are of concern. *Environmental Pollution,* 152, 746-749. WoK cited 33 times.

This paper directly led to EFSA review of arsenic in EU diets.

[6] Meharg AA, Deacon C, Campbell RCJ, Carey A-M, Williams PN, Feldmann J, Raab A. (2008) Inorganic arsenic levels in rice milk exceed EU and US drinking water standards. *Journal Environmental Monitoring,* 10, 428-431. WoK cited 22 times.

This paper directly led to the UK FSA issuing advice that children <4 should not drink rice milk.

[7] Sun, G-X, Williams PN, Carey A-M, Zhu Y-G, Deacon C, Raab A, Feldmann J & Meharg AA (2008). Inorganic arsenic in rice bran and its products are an order of magnitude higher than in bulk grain. *Environmental Science & Technology.* 42, 7542-7546). Wok cited 69 times.

This paper showed that highest inorganic arsenic levels were identified in stabilized rice bran.

Relevant grant funding:

Initial studies were funded through a Commonwealth Universities PhD Scholarship and two Commonwealth Universities funded Visiting Fellowships (1 year study visits), with all recipients being Bangladeshi. The work was then developed through a series of three BBSRC studentships and two further Commonwealth Universities Visiting Bangladeshi Fellowships.

UK and EU funded grants that followed up on initial findings are as follows:

- 2007-2010, EU Marie Curie training programme, awarded to Meharg and Feldmann (joint PIs), £148,000, funding an RA to look at losses from arsenic from paddy fields through biovolatilization.

- 2007-13, various FSA awards totalling £191,000 (review of arsenic and rice/study the effects of cooking on removal of arsenic in rice/arsenic in meat products/ arsenic speciation in fruit and vegetables in geogenically arsenic elevated regions of the UK), awarded to Meharg and colleagues.

- 2007-2011, BBSRC-DFID, awarded to Meharg (PI), Feldmann & Price, £650,000, to study genetic approaches to lowering inorganic arsenic content in rice.

- 2009, NHS, awarded to Meharg and Feldmann, £12,000, to look at arsenic and breast cancer.

- 2010, BBSRC, awarded to Meharg (PI) and Price, £29,000, capacity building for arsenic and rice research in Asia and Africa.

- 2012-16, BBSRC, awarded to Price (PI), Meharg and Salt, £1,100,000, to look at genetic dissection of traits, with arsenic being a major focus, for sustainable water use in Bangladeshi rice.

4. Details of the impact

Building on scientific studies published from 2002 onwards, the direct impact of arsenic and rice investigations within the assessment period (2008-2013) were based on human health impacts, resulting in action by regulators, legislators, consumers and the food industry.

The first assessment period impact was when focus turned to rice products and it was hypothesised that baby rice and rice milk might be problematic, resulting in the first papers in this area [5 & 6 above], which were critical of the lack of legislation regarding arsenic in foods. As a result of these studies, and those that the FSA had commissioned itself, the FSA advised in May 2009 the following: *'As a precaution, toddlers and young children between 1 and 4.5 years old should not have rice drinks as a replacement for cows' milk, breast milk, or infant formula. This is because they will then drink a relatively large amount of it, and their intake of arsenic will be greater than that of older children and adults relative to their bodyweight. This is both on nutritional grounds and because such substitution can increase their intake of inorganic arsenic, which should be kept as low as possible. A daily half pint or 280 millilitres of rice drink could double the amount of the more harmful form of arsenic they consume each day"* [a]. Thus the FSA directly acted on the findings and advice of the Aberdeen University rice milk paper.

The Aberdeen studies on arsenic in rice culminating in the baby rice and baby milk surveys also prompted a major reassessment in 2009 of inorganic arsenic exposure of the EU populace by the EFSA [c]. This review by an assembled expert panel reached the same conclusion as had the Aberdeen studies on both rice milk and baby rice. Another major conclusion from this EFSA review was that the World Health Organization's inorganic arsenic Provisional Maximum Tolerable Daily Intake (PMTDI) was based on flawed calculations, was thus too high, and was not scientifically sustainable. The Aberdeen group had initiated this debate through its series of papers on rice, and indeed was the first and most vocal critic of this PMTDI with respect to food intakes. As the WHO PMTDI represented the only international benchmark of inorganic arsenic intake in any ingested item, it had been widely used to justify that inorganic arsenic intakes from rice were 'safe'. This was a highly flawed argument that did not stand scientific scrutiny, as rice is the dominant source of inorganic arsenic globally, not water. While both the WHO and EU have set strict and low levels of what is the maximum allowed inorganic arsenic in drinking water, given that there are regions of the world that suffer from naturally elevated arsenic in drinking waters, they have not set food standards for inorganic arsenic. The EFSA review and criticism of the PMTDI led directly to rapid withdrawal of this WHO standard. The Aberdeen group published a critique of the current state of arsenic standards globally (Meharg AA & Raab A (2010) Getting to the bottom of arsenic standards and guidelines. *Environmental Science & Technology 44,* 4395–4399) which was published before the WHO withdrew their arsenic PMTDI.

A Dartmouth College PNAS study on baby rice in 2011 which followed up in a US context the Aberdeen group's earlier work on elevated arsenic concentrations in rice and the need to regulate arsenic in food, received considerable global media coverage and has led to the US congress asking the US FDA to consider setting arsenic standards in food, (http://www.pnas.org/content/108/51/20656.full).

The EU, WHO and USA are all currently considering setting arsenic standards in food as illustrated by the EFSA (2009) review and FDAs published concerns and timelines (http://www.fda.gov/forconsumers/consumerupdates/ucm319827.htm) and specific calls by the US congress to set standards for arsenic in rice (http://www.huffingtonpost.com/2012/09/21/rice-act-arsenic-delauro-pallone-lowey_n_1904490.html).

The BBSRC have explicitly identified Meharg's work regarding arsenic in rice as part of their "Our Impact": http://www.bbsrc.ac.uk/research/impact/arsenic-levels-in-food.aspx

Claimed impact as defined by REF guidance includes: evidence of awareness of health risks and benefits by consumers; clinical and dietary guidelines have changed; public health, well-being has improved and public behaviour has changed; documented changes to public health policies; advisory committees and guidelines; decisions by regulatory authorities has been influenced by research.

5. Sources to corroborate the impact

[a] The UK Food Standards Agency commissioned two studies, one on rice milk and one on baby rice, directly following publication of Aberdeen studies on this topic (Meharg et al. 2008 a,b) [5 & 6], with their findings corroborating those of the Aberdeen group. It issued public advice for children <4 not to drink rice milk.
http://www.food.gov.uk/news/newsarchive/2009/may/arsenicinriceresearch

[b] 2009 press story around this time showing the FSA was directed by UoA study:
http://www.dailymail.co.uk/news/article-1186722/Rice-milk-arsenic-contamination-prompts-food-watchdog-warning-children-stop-drinking-it.html

[c] EFSA commissioned a major review of arsenic in the EU diet following the Aberdeen arsenic in baby rice study (Meharg 2008) [5] along with the mounting evidence produced by the group that showed that arsenic in rice was of wide concern, starting with Williams et al. (2005) [3]. This report concluded that arsenic in rice was of concern to high consuming groups, including babies, and that action should be taken to lower inorganic arsenic in the EU diet.
http://www.efsa.europa.eu/en/efsajournal/pub/1351.htm

[d] Following the publication of the ESFA's report which criticized the WHO's Provisional Maximum Tolerable Daily Intake (PMTDI) as having a poor scientific grounding, combined with Aberdeen's own critique of the current arsenic standards globally, (Meharg AA & Raab A (2010) Getting to the bottom of arsenic standards and guidelines. *Environmental Science & Technology 44,* 4395–4399), this standard was removed. See page 3 of
http://www.who.int/foodsafety/chem/summary72_rev.pdf

Below is an examples of the extensive media coverage garnered (i.e. ~ 80,000 hits on Google when the string "Meharg arsenic rice" is searched):

[e] Sample newspaper coverage of Aberdeen's arsenic in baby rice research (Meharg et al. 2008) [5]: http://www.telegraph.co.uk/health/healthnews/8440126/Arsenic-and-toxic-metals-found-in-baby-foods.html

[f] An example of industry response to the Aberdeen research findings:
http://www.lundberg.com/Info/Arsenic/Arsenic_links.aspx