

Impact case study (REF3)

Institution: The Open University		
Unit of Assessment: A04 Psychology, Psychiatry and Neuroscience		
Title of case study: Raising awareness, increasing support, and changing policy and behaviour regarding the health effects of long-term, low-level exposure to organophosphates		
Period when the underpinning research was undertaken: 2010-2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Dr V Harrison	Senior Lecturer in Psychology	2011-onwards
Period when the claimed impact occurred: 2014-2020		
Is this case study continued from a case study submitted in 2014? No		
1. Summary of the impact		
<p>Organophosphate compounds (OPs) are highly toxic substances that are used extensively in agricultural, industrial, transportation, and domestic settings. This research has demonstrated the potential ill-health effects associated with long-term low-level (LTLL) exposure in certain occupationally exposed groups (in response to the Committee on Toxicology's recommendations), finding that OP users report a specific pattern of cognitive and neurobehavioral deficits, as well as psychiatric symptoms, even after only low-level exposure.</p> <p>These findings have been used to raise public, professional and governmental awareness of the risks and health-related outcomes associated with OP exposure, which has led to behaviour change at both an individual and industrial level in the farming and aviation industries. Furthermore, this work has been used to inform a new medical protocol designed to better recognise and support those who have been exposed to OPs. Harrison's findings have also been used in medico-legal work, in direct support of compensation claims made against airlines for toxic fume exposure.</p>		
2. Underpinning research		
<p>OP pesticides are one of the most widely used insecticides in the world and are considered by the World Health Organisation (WHO) to be one of the most hazardous pesticides to vertebrate animals. They are responsible for poisoning large numbers of people worldwide, particularly in developing countries where adequate protective measures may be lacking (De Silva et al, 2006; WHO report, 1990). Concern about their effects on human health has been growing as OPs are increasingly used throughout the world for a variety of agricultural, domestic, and industrial purposes.</p> <p>The neurotoxic effects of acute OP poisoning are well established and involve inhibition of the enzyme acetylcholinesterase, causing changes in peripheral, autonomic, and central nervous system function (cholinergic crisis). However, the impact of LTLL exposure to OPs on human health remains unclear as research findings are inconsistent. Because many more individuals are likely to be at risk of LTLL exposure than acute poisoning, establishing whether low-level exposure to OPs causes ill-health is of the utmost importance.</p> <p>Since 2004, Harrison has worked closely with Dr Mackenzie-Ross, a Clinical Neuropsychologist from University College London specialising in the impact of toxins on psychological function. Together, their work with participants from occupational cohorts known to have LTLL exposure to OPs has sought to establish whether there is a link between this type of exposure and ill-health [O1-O6]. Working with farmers who have regularly used OP-based sheep-dip pesticides, their research has identified a subtle but specific pattern of neurobehavioral and psychiatric deficits compared to non-exposed controls [O1 and Mackenzie-Ross et al., 2010]. Further, they have supported and confirmed this pattern with comprehensive reviews and meta-analyses of the literature [O3-O5 and Mackenzie-Ross & Harrison, 2020].</p>		

In parallel to this, **Harrison** and Mackenzie-Ross have carried out similar work with pilots [O2, O6]. Cabin air on commercial aircraft is sometimes contaminated with jet engine oils containing OPs [O2]. Aircrew have long complained of chronic ill-health and cognitive impairment following exposure to contaminated air, but a debate is ongoing about causation, diagnosis, and treatment of long-term effects. The incidence of contaminated air events is difficult to quantify, as commercial aircraft do not have air quality monitoring systems on board. **Harrison** and Mackenzie-Ross's research with pilots has investigated whether an association exists between exposure to contaminated air and neuropsychological impairment. By examining pilots' profile of psychiatric symptoms and cognitive performance using well-validated and standardised measures, the team found evidence of subtle deficits compared to standardised norms; and that the pattern of deficits mirror those evidenced in other OP-exposed cohorts (i.e., farmers). In particular, they show impairment in attention, psychomotor speed and visual sequencing [O6, O5]

Given the potential negative impact of OP exposure, and the safety implications of these findings, they have been involved in a number of impact activities to help prevent future harm. For example, one of their articles [O2], has explicitly sought to increase professional and organisational awareness of this issue by highlighting the problem of OP exposure on various aircraft. Their research is also actively used by OP-related support and lobby groups in aviation and agriculture to raise public and professional awareness about the potential dangers of OP exposure.

3. References to the research

All items referenced here were blind peer-reviewed.

- O1.** **Harrison, V.**, & Mackenzie Ross, S.J. (2016) Anxiety and depression following cumulative low-level exposure to organophosphate pesticides. *Environmental Research*, 151, 528-536. <https://doi.org/10.1016/j.envres.2016.08.020>
- O2.** **Harrison, V.**, & Mackenzie Ross, S.J. (2016) An emerging concern: Toxic fumes in airplane cabins. *Cortex*, 74, 297-302. <https://doi.org/10.1016/j.cortex.2015.11.014>
- O3.** Mackenzie Ross, S.J., & **Harrison, V.** (2016) What's your poison? Neurobehavioural consequences of exposure to industrial, agricultural and environmental chemicals. *Cortex*, 74, 353-357. <https://doi.org/10.1016/j.cortex.2015.12.002>
- O4.** Mackenzie Ross, S.J., McManus, I.C., **Harrison, V.**, & Mason, O. (2015) Reflections on the process of using systematic review techniques to evaluate the literature regarding the neurotoxicity of low level exposure to organophosphate pesticides. *Environment International*, 92-93, 569-573. <https://doi.org/10.1016/j.envint.2015.10.009>
- O5.** Mackenzie Ross, S.J., McManus, I.C., **Harrison, V.** & Mason, O. (2013) Neurobehavioral problems following low-level exposure to organophosphate pesticides: a systematic and meta-analytic review. *Critical Reviews in Toxicology*, 43(1), 21-44. <https://doi.org/10.3109/10408444.2012.738645>
- O6.** Mackenzie Ross, S.J., **Harrison, V.**, Madeley, L., Davis, K., Abraham-Smith, K., Hughes, T., & Mason, O. (2011) Cognitive function following reported exposure to contaminated air on commercial aircraft: methodological considerations for future researchers. *Journal of Biological Physics and Chemistry*, 11(4), 180-191. <https://doi.org/10.4024/30MA11A.jbpc.11.04>

4. Details of the impact

The research of **Harrison** and Mackenzie-Ross has had five kinds of impact: (1) increasing public and professional awareness of the hazards of organophosphate (OP) exposure; (2) raising government awareness through parliamentary discussion; (3) promoting changes within the aviation industry to increase staff and passenger safety; (4) promoting changes to healthcare delivery to better support those exposed to OPs; and (5) informing medico-legal work to support compensation cases.

(1) Increasing public and professional awareness and changing behaviour

Harrison and Mackenzie Ross have maximised the reach of their research through publication across a wide range of popular and occupational media, including high circulation media such as the Daily Mail, The Guardian, The Telegraph, BBC [C1]. They have also targeted articles at two distinct occupational groups known to have LTLL exposure to OPs (farmers and pilots), for example, publishing work on the health consequences of OP exposure in outlets such as Farmers' Weekly [C1]. Moreover, their work with pilots featured in an article written by **Harrison** for 'The Conversation' in 2015, which received over 250,000 views online in the first month [C1]. Developing this line of impact, one of their research articles [O2] explicitly highlighted the problem of OP exposure on various aircraft to raise professional awareness of this issue. This was published in a special edition of Cortex focusing on neurotoxicity and featured in a number of news articles. This work subsequently informed the British Psychological Society, Professional Practice Board position statement: Aviation and Aerospace Psychology: Pilot Mental Health and Wellbeing, that recognises the potential harm of poor air quality in aircraft [C2 – testimonial 5].

Harrison's academic and media articles have been actively used by OP-related support and lobby groups in aviation and agriculture, aiding the groups' recognition of OP-related symptoms (and thus increasing their support), and helping them to better highlight the potential dangers of OPs and encourage safer working practices [C2 – testimonials 1 and 2]. For example, the Aertoxic Association have "*used the findings countless times to try and get others to treat the illness as 'real'*", and the Sheep Dip Sufferers Support group describe our work as "*pioneering*" work that they use to "*support and inform others*", leading them to better "*understand the cumulative effects [of OPs] at even quite low levels of exposure*" [C2 – testimonials 1 and 2].

Our survey of 95 farmers indicates that these awareness raising activities have directly resulted in behaviour change. Farmers who have heard of our work (58%) perceived OP exposure to be significantly more risky (mean=3.16, sd=0.92) than farmers who have not (mean=2.60, sd=0.84; (t(93)=-3.06, p=.003); with 55% implementing more protective behaviours as a result [C3].

(2) Raising awareness in parliament

The work of **Harrison** and Mackenzie Ross has also informed campaigns designed to improve safety policies for occupational groups who may be regularly exposed to OPs, which has led to extensive discussion of their research (and this issue more broadly) in Parliament. For example, their research findings have been presented (by **Harrison** and co-authors) to Peers (including the Countess of Mar), government ministers (such as George Eustice, Andy Burnham and Jessica Morden), and the departments responsible for the regulation of safety for the relevant occupational groups: the Department for Environment, Food and Rural Affairs (DEFRA) and the Civil Aviation Authority (CAA) [C2 – testimonials 1 and 5; C4]. Specifically, on May 14th 2014, **Harrison** and Mackenzie Ross presented findings from their research to a Select Committee, led by Rt Hon Andy Burnham MP (then the Shadow Secretary of State for Health) at the House of Commons. Following this meeting, Burnham called for an independent inquiry into health problems following exposure to sheep dip, which led to further debate on the topic in parliament [C4], which is ongoing.

Their research was also considered by the Committee on Toxicology, informing their statement on the ill-health effects of organophosphates. Although the committee's conclusions about the consequences of LTLL exposure were mixed, following the work of **Harrison** and colleagues, they concluded that *"there is an excess of multiple neuropsychiatric symptoms in people who have been exposed to organophosphates at levels insufficient to cause overt acute poisoning"* [C5].

(3) Promoting changes in the aviation industry

Harrison and Mackenzie Ross' work has significantly contributed to a growing body of work in this field over the last decade, which (combined) has led to recognition of the importance of this issue for the industry. For example, their research with pilots provided a significant contribution to a WHO paper, which found contaminated aircraft air *"can reasonably be linked to acute and chronic symptoms, findings and diagnoses, thus establishing causation"* [C6].

Due to commercial sensitivities, industrial change is difficult to evidence but the testimonial provided by a former British Airways pilot, union Health & Safety representative, and co-founder of the Global Cabin Air Quality Executive (GCAQE) verifies that as a result of the work carried out by **Harrison** and Mackenzie Ross, and their contribution to the cumulative research in this area, *"we have started to see some real changes happening in this industry"*. For example, EasyJet have commissioned a new cabin air filtration system to help protect against negative health outcomes, the ICAO have issued training guidelines for airlines outlining what crews should be trained to do in terms of air quality and contamination issues, and engine oil cans now come with clear written warnings that state *"Do not breathe mist or vapor from heated product"* [C2, C7]. The co-founder of GCAQE acknowledges this as a significant shift, with the aviation industry and oil companies *"admitting that you should not breathe in pyrolyzed oil fumes"* [C2 – testimonial 3].

(4) Providing tailored healthcare provision

In addition to the changes in industry, a working group has been commissioned to create a special care pathway within the NHS to support patients who have experienced fume events. Again, this is the result of the cumulative research in this area (including that of **Harrison** and Mackenzie Ross), that has led the Civil Aviation Authority to acknowledge that ill health symptoms can arise as a result of fume event exposure [C8].

Furthermore, the GCAQE currently recommend that pilots, cabin crew or passengers who believe their health has been affected by OP-exposure should undergo neuropsychological testing based on the test batteries and protocol used in Mackenzie Ross and **Harrison's** work. Additionally, GCAQE will release a new medical protocol in 2021 that will give guidance on the identification and support of those who have been exposed to toxic fumes, which has been directly informed by the work of Mackenzie Ross and **Harrison** [C2 – testimonial 3].

(5) Use in medico-legal settings

Finally, **Harrison** has worked directly with expert witnesses who have used their research in medico-legal work aiming to establish culpability for ill health [C2 – testimonials 4 and 5]. For example, **Harrison** and Mackenzie Ross' work was recently used by an expert witness in a workers' compensation case in the US, which resulted in significant compensation being awarded to the complainant, an aircraft Captain who had become unwell as a result of OP exposure [C2, C9]. As highlighted in the expert witness' testimonial, this research explicitly played a role in the success of this case: *"This finding was clearly awarded based on the evidence investigating chronic exposure to oil fumes in the aviation setting, and Dr Harrison's work helped to inform the testimony I gave to this effect."* [C2 – testimonial 4]. There have also been a number of other cases brought against the aviation industry, many of which have been settled out of court with non-disclosure agreements [C2 – testimonials 4 and 5]. None-the-less, medico-legal experts have provided expert advice, in part based on **Harrison's** work, to the

legal teams representing the complainants. In her testimonial, the Head of Research for the Global Cabin Air Quality Executive suggests that these settlements are likely to be the result of the cumulative weight of the research in this area: “*There have also been several other major cases that have been settled in the United States, as a result of much of the research work that has taken place over the years*” [C2 – testimonial 4].

In addition, **Harrison** and Mackenzie Ross’ research was employed by the aviation lawyer representing the families of Matt Bass and Richard Westgate, as part of the case investigating whether or not toxic exposure could account for their deaths [C10]. These cases are now part of a major class action led by Thompson’s solicitors [C2 – testimonial 5].

5. Sources to corroborate the impact

- C1. News articles. A collection of articles and interviews published in The Conversation, mainstream media, and in industry-specific publications outlining the research and/or findings of **Harrison** and Mackenzie Ross.
- C2. Testimonials relating to impact.
- C3. Report. Short report outlining primary data collection about impact and providing direct evidence of a relationship between awareness of our research and behaviour change in farmers.
- C4. Evidence of consideration of research by parliament from documented sources of information in the public domain. Available from:
<https://gmandchemicalindustry9.wordpress.com/tag/sheep-dipping/>
<https://www.fwi.co.uk/news/environment/shadow-health-secretary-calls-sheep-dip-inquiry>;
<https://hansard.parliament.uk/commons/2015-06-10/debates/15061062000002/OrganophosphateSheepDip> (the referral to ‘independent studies by University College London’ refers to the work listed in Section 3 ([O4-O6], which was co-authored with UCL academics).
- C5. Committee on Toxicology Report Summary and Reference List.
<https://cot.food.gov.uk/sites/default/files/oplaysummary.pdf>
- C6. WHO Report. Michaelis et al (2017). Available from:
https://www.euro.who.int/_data/assets/pdf_file/0019/341533/5_OriginalResearch_AerotoxicSyndrom_ENG.pdf
- C7. Collection of Guidance Reports and Articles evidencing recent changes in the aviation industry.
- C8. Article outlining new medical protocol for fume exposures. CAA (2017):
<https://www.caa.co.uk/Passengers/Before-you-fly/Am-I-fit-to-fly/Guidance-for-health-professionals/Aircraft-fume-events/>
- C9. Court hearing documents. Evidence of workers’ compensation case for toxic fumes exposure in Oregon.
- C10. Report. Cannon (2016). <https://doi.org/10.4024/N08CA16A.ntp.12.02>