**Spreading the message of antimicrobial resistance: A detailed account of a successful public engagement event**

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**Keywords**

Antimicrobial resistance
Outreach
Public engagement
Practical
Education
Science Communication

## Abstract

The increase in Antimicrobial resistance (AMR) microorganisms has been exacerbated by exposure to antimicrobial drugs (e.g. antibiotics). A solution to AMR may require academic researchers to not only contribute to the drug discovery pipeline through laboratory research, but also to engage and inform non-specialist audiences using a variety of interventions in order to change behaviour towards our use of antibiotics. In this paper, the authors describe a hands-on public engagement event focusing on AMR. 'A Spoonful of Soil', was created by drawing on the past experiences of the delivering team (also described), with planning focusing on clear concise messages, selection of an appropriate audience and ensuring the event would be of significant interest to the audience. The event had a significant footfall of over 300 visitors. Key messages which aimed to raise awareness of AMR and educate visitors on the actions and behaviours that can help address the global issue of AMR were delivered by appropriate experts successfully, however success in reaching audience cannot be concluded from the feedback and evaluation gathered.

## Introduction

The increase in antimicrobial resistant (AMR) microorganisms has been exacerbated by exposure to antimicrobial drugs (e.g. antibiotics). This has led to existing medicines becoming ineffective which in turn reduces the capacity to treat microbial infections (WHO 2017). In 2016, the Wellcome Trust Monitor report (Ipsos Mori 2016) described a fundamental misunderstanding surrounding AMR in the wider UK population. When asked to self-report their understanding of antibiotic resistance, 56% of respondents considered their knowledge very good or good, with only 19% stating they had little or no understanding. Respondents, who had heard of antibiotic resistance were asked to state what they understood by this term. The most frequent response (33%) indicated a belief that antibiotic resistance referred to the human body becoming resistant to antibiotics, rather than the antibiotic resistant microorganisms. The next most frequent theme was that 'antibiotics don't work' (20%), and that 'antibiotics are overused' (20%). Forty-one percent of respondents understood that antibiotics only work against bacteria, with 38% suggesting action against viral infections, 21% against fungal injections and 15% specifically mentioning flu. Similar results have been found elsewhere (e.g. Brookes-Howell, Elwyn et al. 2012, YouGov 2014). This acknowledges that while some members of the public understand the issues surrounding AMR, there is a need for further education.

The 'fight' against antimicrobial resistance (AMR) requires a change in behaviour across society. Currently, the misuse of prescribed antibiotics, over-the-counter/internet purchase of antibiotics, and the use of antibiotics in industries such as farming are contributing to increase resistance of bacteria to antibiotics (Holmes, Moore et al. 2016). Meanwhile, scientists are increasingly working on novel interventions such as bacteriophage therapy (e.g. Reindel and Fiore 2017), antimicrobial compounds e.g. ruthenium (e.g. Southam, Butler et al. 2017) and chemical carriers to enhance antimicrobial effect e.g. nanozeolites (e.g. Redfern, Goldyn et al. 2017) to ensure society remains able to fight bacterial infections (e.g. Tillotson and Theriault 2013). However, only eight of the 51 new antibiotics in development was an 'innovative treatment' (Kmietowicz 2017) and further hindered by the regulation and time required to bring these to market is significant.

A solution to AMR will require academic researchers to not only contribute to the drug discovery pipeline through laboratory research, but also to engage and inform non-specialist audiences using a variety of in order to change behaviour towards our use of antibiotics.

A range of different science communication activities have been used by academic scientists to engage with audiences and many are translatable to AMR:

- developing practical classes/events for schools and the public (e.g. Redfern, Malcolm et al. 2014)
- participation in science festivals (e.g. Redfern, Burdass et al. 2013)
- working with museums/art galleries (e.g. Alpert 2009)
- citizen science projects (e.g. Follett and Strezov 2015)
- public lectures (e.g. http://www.rigb.org/christmas-lectures)
- school visits (e.g. Laursen, Liston et al. 2007)
- book clubs (e.g.Verran 2013)
- use of digital media e.g. social media, blogs, web-based apps (e.g. Scott 2013, Ranger and Bultitude 2014)
- developing and designing games (e.g. http://gamedrlimited.com/)
- podcasting (e.g. Racaniello 2010)

Considerations such as: developing a message, selecting the appropriate audience, advertising to an audience, and that the activity/event/intervention is of significant interest to engage the audience, are all important when developing science communication activities. In addition to ensuring the event is attended, careful attention is needed when determining if an event is successful. Evaluation of public engagements events should encompass both qualitative and quantitative data collection and analysis, and the evaluation methods must be considered from the very start of planning (Bennett, Jennings et al. 2011). This paper describes the design, delivery and evaluation of a multi-faceted, one-day public engagement event held at the Manchester Museum of Science and Industry in 2016 (http://msimanchester.org.uk/) entitled 'A Spoonful of *Soil'.* The aims of the event were to:

- raise awareness of AMR
- educate visitors on actions and behaviours that can help to address this global issue

The team delivering the event used findings from previous science communication events to design, plan and evaluate this session. These are outlined in Table 1 and described in detail below.

**The Microbiology Society 'Antibiotics Unearthed'**

The Small World Initiative (SWI - http://www.smallworldinitiative.org) was piloted at Yale University, USA, in 2012. The programme aimed to engage college-level students with authentic microbiology research (in comparison to prescribed cookbook practical classes), by culturing soil in the pursuit of novel antimicrobial producing microorganisms. The SWI has been successful (e.g. Caruso, Israel et al. 2016, Davis, Sloan et al. 2017), in both its engagement and uptake with the microbiology higher education community across the US and worldwide, and also by delivering on its educational remit.

Following the success of SWI in the US, the Microbiology Society in the UK developed a programme inspired by the SWI, called Antibiotics Unearthed. The programme had three distinct aspects. Firstly, it was run as an authentic research project with undergraduate students in the United Kingdom and Ireland mirroring the SWI project in the US. Secondly, it was designed and developed to engage high school students (16-18 years old) in the potential discovery of antibiotics from soil microbes, with a major focus on education about microbiology and in particular about antimicrobial resistance. Thirdly, it was also developed as a citizen science project (https://www.microbiologysociety.org/education-outreach/antibiotics-unearthed.html) with an associated PhD programme that sought to discover if citizen science is an effective method for stimulating/engaging members of the public, particularly around the issues of AMR.

Members of the team that developed the 'A Spoonful of Soil' event were part of the Antibiotics Unearthed initiative. They have delivered Antibiotic Unearthed with MSc students annually and they also have experience of delivering Antibiotics Unearthed to two high schools over a six-week period, and they have key project roles in the Citizen Science Project. Involvement in these events provided some key learning outcomes to be considered with any future iteration of this hands-on, practical microbiology (table 1). Activities undertaken by participants as part of the Spoonful of Soil include soil collection, soil sample dilution, inoculation and streaking onto agar to identify any antimicrobial producing microorganisms.

**Bad Bugs Book Club**

The Bad Bugs Bookclub (Verran 2013) comprises scientists and non-scientists who discuss novels where infectious disease forms part of the plot. Over an eight-year period, discussion and reading guides for over fifty novels have been posted on the Bookclub website (http://www2.mmu.ac.uk/engage/what-we-do/bad-bugs-bookclub/).

Although some post-apocalyptic scenarios mention antimicrobial resistance in passing, there are few novels which focus specifically on the topic. *A Fierce Radiance* (Belfer 2011) describes the industrial production of antibiotics during World War Two, the prioritisation of combat troops to receive treatment, and the impact of antibiotics on public health, providing valuable insight into the impact of antibiotics on the treatment of a wide range of infections (http://www2.mmu.ac.uk/engage/what-we-do/bad-bugs-bookclub/A-Fierce-Radiance-Meeting-Report.docx). *The Deep Zone* (Tabor 2013) not yet part of the Bookclub resource, is concerned with the discovery of new antibiotics in unusual environments (caves), couched in industrial and political espionage – inadvertently touching upon the very real searches currently ongoing across the globe (e.g. Piddock 2015). NESTA (http://www.nesta.org.uk/) published a collection of short stories called *Infectious Futures* (NESTA 2015). Writers had been commissioned to address aspects of the post-antibiotic era. Comic books such as *Surgeon X 46* (Kenney, Watkiss et al. 2017), radio plays (e.g. Val McDermid's Resistance - https://www.valmcdermid.com/category/radio/) and other public information efforts such as TV documentaries (e.g. Horizon, BBC http://www.bbc.co.uk/programmes/b044mkxt) and podcasts (e.g. Radiolab's Staph Retreat - http://www.radiolab.org/story/best-medicine/) are similarly attempting to engage the public in discussion about AMR.

**Café Scientifique: antibiotic resistance**

Café Scientifique was launched in Leeds in 1998; an informal gathering of scientists and members of the public from all walks of life involved in conversation about scientific issues including the growing problem of antibiotic resistance superbugs. One such event took place at an Arts Centre in Suffolk in Spring 2015. This evening event was attended by more than 70 members of the public with two speakers, one of the authors and a clinical microbiologist, as well as a graphic artist who visually records the event in real time. The evening was divided into three distinct session: introductory talks by the two speakers (20 mins each); a 20-minute break for mingling and an opportunity to buy food and drink; finally, a 40-minute discussion with active participation and questions from the audience. This session described the life-changing effects of antibiotic discovery as well as the science that underpins the spread of antibiotic resistance among bacterial cells.

**Videos of AMR**

One of the key messages that is important to share with the public is how easily antibiotic resistance genes can spread among bacteria to generate antibiotic resistant superbugs. Short animations were created to demonstrate the underlying mechanisms of horizontal and vertical gene transfer. These are available on YouTube at https://youtu.be/YT9UpgkgBoo.

**A Spoonful of Soil Event**

In 2016, the authors delivered a multi-faceted public engagement event focusing on antibiotic resistance and its impact on human health. The planning of this event drew heavily on the key learnings and ideas generated and refined through the activities described above (Table 1). The event was held as part of a Saturday science programme called Pi (Platform for Investigation https://www.msimanchester.org.uk/whats-on/platform-for-investigation) and held within a predefined space in the entrance hall of the Manchester Museum of Science and Industry, ensuring footfall on the day. The event was advertised using the standard museum advertising platforms e.g. website and social media. Advertisements contained instructions for visitors to bring their own soil samples and gave details on a book club timetabled to occur after the hands-on event had finished.

The activities were set out in a horse-shoe shape. Participants started at a specific starting point, Activity 1, and then flowed around the different activities in a clockwise direction (figure 1). To encourage participants to engage with all activities in the event, and in the designated order, each family/group received a 'passport', upon which they would receive a coloured sticker (figure 2) specific to a particular each stage of the event. Upon completion of the passport (at stage four), participants were invited to leave their email address and as well as any comment they felt relevant to the event for a chance to win a child's lab coat.

**A Spoonful of Soil - Method**

*Activity 1 - Have you ever had antibiotics?*

All activities were risk assessed to ensure the safe delivery, including consideration of biosafety. The event did not use pre-prepared cultures on agar plates, opting instead to provide images of what a participant might expect to find growing on an agar plate inoculated with soil. Additionally, post-event, inoculated plates were incubated at 30°C, in order to reduce the likelihood of culturing anything potentially pathogenic (ASE 2001). Stage one of the activity was used as a hook, conversation starter and a guide for the demonstrator as to the level of knowledge the participants had around the topics of antibiotics. Visitors were asked to consider their personal experiences of antibiotics and assessed their understanding of 'where antibiotics come from'. Participants were asked to provide a mark on a hand-drawn map of the human body (figure 3) to indicate the location of an injury/illness for which they had received prescribed antibiotics, which was a visual, engaging and family-oriented activity. Following this, participants were asked which microorganisms (from a list containing fungi, bacteria, viruses, algae and protozoa) they thought produced antibiotics and which microorganisms are killed by antibiotics. Their answers collected via tally table (table 3).

*Activity 2 - How do we find new antibiotics?*

A hands-on experiment was developed, inspired by typical microbiology laboratory practical classes and the Small World Initiative/Antibiotics Unearthed programmes. Advertising material for the event asked participants to bring soil samples to the event for testing. This activity required access to running water and electricity. The team brought soil from a garden as contingency.  Almost all participants used contingency soil brought by the team. Participants weighed out one gram of soil and diluted it in 10ml of water. Following this, 0.1ml (using a reusable plastic pipette) was spread (using a disposable plastic spreader) onto a nutrient agar plate pre-labelled with a unique number. The participant was provided with a postcard containing the web address (https://flic.kr/s/aHskvZMRMs) to a photo gallery where photos of each plate, alongside their unique identifying number and any comments, were uploaded one week after the event (following a three-day incubation at 30°C). During this activity, volunteers were students enrolled on a biological science or a healthcare science undergraduate degree. Students were asked to discuss the concept of microorganisms producing antibiotics and the scientific background to the activity as well as providing an overview of the experimental method, and in particular, what would happen to the plates post-event (i.e. incubation). Volunteers were asked to pass on any questions they did not feel suitable to answer to one of the academic staff at activity 1, 3 or 4. Academic staff periodically watched the engagement between students and participants to ensure the correct scientific information and methodologies were being provided/demonstrated.

*Activity 3 - Why is antimicrobial resistance an emergency?*

Activity three, participants engaged with two research microbiologists. The aim was for informal conversation, but the microbiologists focused their conversations on the question “why antimicrobial resistance is an emergency?”, aided by images and props to help visualize and prompt conversation. The researchers had produced a tablecloth that had photographs of two agar plates that had been used to culture soil bacteria (figure 4). The plates had clear zones of inhibition caused by antimicrobial production by bacterial colonies. Participants were asked to Hunt the Zone of Inhibition. The microbiologists also brought and distributed literature, in addition to infographics created as part of the O’Neill report on antimicrobial resistance (https://amr-review.org/infographics.html). This activity, and the infographics gave participants a chance to discuss prescription rates and issues associated with use of antibiotics in the healthcare setting as well as the repercussions related to the use of antibiotics within intensive farming. Evaluation was collected through informal conversation, predominantly through noting the themes visitors had discussed.

*Activity 4 - “What can I do to help?”.*

The final stage of the event focused on the question “what can I do to help?”. Here, two microbiologists were able to answer any remaining questions and provide examples of actions everybody could do to help the fight against AMR (for example, only requesting/taking antibiotics from a doctor when an infection is caused by bacteria), including information on how visitors could become Antibiotic Guardians (http://antibioticguardian.com/). Although a formal account of questions and discussion points was not kept, key comments were noted.

*Activity 5 - Book Club*

*A Fierce Radiance* (Belfer 2011) was identified for this event and advertised on website. The bookclub was planned to take place after the above activities had finished.

**A Spoonful of Soil - results**

An overview of results can be found in table 2. Over 300 visitors attended over the six-hour period (as estimated by museum staff). A total of 91 passports were received, with family groups often completing one passport. OF the 91 passports, 43 provided comments and were all positive (e.g. “very informative, very well presented”).  Only three of the comments specifically mentioned antibiotics (“very informative, need to remember to finish my course of antibiotics!”).

*Have you ever had antibiotics?*

The image of the body had 220 marks, representing illness/issues requiring antibiotics across the whole body. The majority of marks were relating to common infections such as skin complaints, tonsillitis and sinus issues. Other marks related to more complex infections such as hip-replacements and septicaemia.

There were 82 responses to the first question and 76 responses to the second, the majority of responses to both questions were correct (Table 3). Whilst 84% of respondents (n=67) knew “which microorganisms produce antibiotics?”, a lower percentage (68.4%) knew “which microorganisms are killed by antibiotics?” (n=52). This mirrors the issues described in the Wellcome Trust report (Ipsos Mori 2016) that members of the public may not understand that antibiotics treat bacterial infections, and not viral or mycological infections.

*How do we find new antibiotics?*

Following incubation of agar plates inoculated with diluted soil, 120 sets of images were uploaded to the dedicated Flickr webpage described above. These images comprised 143 individual agar plates, because some family groups were uploaded under one unique identifying number (e.g. figure 5). Every agar plate supported microbial growth, with zones of inhibition visible on the majority of plates. All soil samples used had been provided by the event coordinators, because no members of the public brought their own soil samples. Although there were specific opportunities for participants to follow up after the event (via Flickr and email), post-event technological issues prohibited visitors from finding the site (and therefore photographs) via the web link provided on the day. Whilst this was disappointing, it was interesting to note that only one person got in touch to inform us of such, whom we were able to successfully then direct to the Flickr site.

*Why is antimicrobial resistance an emergency?*

Stage three: This stage of the exhibition was effective as long as there were two or more science communicators available at any one time. This enabled one communicator to talk to children and encourage them to find the ‘Zone of Inhibition’, while the other science communicator was able to engage in conversation with the adults using the O’ Neil Infographics as a prompt. The informal discussions generated by the infographics provided from the O’ Neil AMR review and the Hunt the Zone of Inhibition game were revealing. The O’ Neil infographic that outlines the scale of the problem by indicating the number of deaths to be caused by antimicrobial resistance in 2050 was introduced to the adults first. This infographic provoked surprise and significant concern. It was clear that although people had heard about the growing problem of antimicrobial resistance they were unaware of the scale or the significance of the problem of AMR. Next, the infographics were used to highlight how antibiotics are used in humans and agriculture, with an explanation of how this leads to environmental pollution by antimicrobial products. The conversation was steered to discuss how societies rely on antibiotics which is leading to increasing levels of antimicrobial resistance in bacteria. Participants were often keen to discuss their own personal experience of antibiotics. It was interesting to note that adults were more comfortable with their children being prescribed antibiotics for infections compared to their own personal use of antibiotics. Conversations often referred to the concept that antibiotics should be used as a last resort and there was a sense of pride in not relying on antibiotics as infection control. In addition, participants were interested to understand why it is important to finish each prescribed course of antibiotics in order to reduce the development of antibiotic resistant bacteria. This knowledge was something tangible that participants felt that they could actively do to make a positive impact in the global fight against antimicrobial resistance. If participants were keen to know more about the science that underpins how antimicrobial resistance development in bacteria, including horizontal and vertical transmission of resistance genes we invited the participants to watch the short animations on the large screens behind the exhibition.

*Book club*

The book club did not take place as nobody presented themselves to the team willing to take part.

## A Spoonful of Soil – discussion

The team prioritised the experience of the visitors but quantitative and qualitative evaluation was carried out to establish the success of the event. Discussions with participants were stimulating, demonstrating engagement and the story of the discovery of antibiotics was appreciated and enjoyed. The use of a passport to monitor where each participant was very useful, as it allowed the team to ensure participants had visited each stage in the correct order. Additionally, of the 91 returned cards, fewer than half (n=43) left written feedback when asked “Do you have any comments about the event?” (and where comments were made, they were uninformative and vague).

Although efforts were made to advertise the event through the Museum website and social media pages, and the University social media, it appeared that visitors were likely already planning to visit the museum. This is evidenced by anecdotal questioning of participants as to whether they had seen the advertising, and the fact that no participants had brought along their own soil samples – which had been emphasised in all advertising. This was a potential risk that had been realised prior to the event and the event team had brought their own soil. Despite this, footfall was sufficient to ensure that the event attracted significant participants. Additionally, the lack of knowledge relating to the advertised book club suggests the advertising did not work and/or considerations such as audience type (families) and time of day (late Saturday afternoon) were not the correct choice for a book club. Events that focus on adult audiences in social spaces (e.g. SciBar and Café Scientifique) may be a better fit for a book club.

In future events, evaluation should not rely solely on feedback cards. Although a formal account of questions and discussion points generated in the conversations with participants would have been valuable for evaluation, the constant flow of participants and limited number of volunteers prohibited a full evaluation. A dedicated ‘evaluator’ would allow for a variety of evaluations including short structured interviews, which may be a more effective choice. Nevertheless, the results suggest that the aim to increase awareness was successful.

to engage visitors with the issues of antimicrobial resistance and inform on how they can help, was successfully achieved.

## Conclusion

A hands-on public engagement event focusing on AMR was successfully delivered by the team. 'A Spoonful of Soil', was created by drawing on the past experiences of the delivering team, with planning focusing on clear concise messages, selection of an appropriate audience and ensuring the event would be of significant interest to the audience. The event attracted a significant footfall of over 300 visitors. The aim was to deliver key messages to raise awareness of AMR and educate visitors on the actions and behaviours that can help address the global issue of AMR. Despite these aims being broad, the team of scientific experts believed they were successfully delivered, however success in terms participant knowledge of AMR cannot be measured using selected evaluation methods. In order to create a more rigorous evaluation, specific aims with measureable objectives should be employed – but it should be noted that these can often be difficult to operate in a busy hands-on event and may provide a particular challenge to those not comprehensively trained in qualitative data collection and analysis. In future, advertising will be prioritised, particularly for events requiring visitor participation. Future events will have volunteers dedicated to evaluation. Other locations, particularly in places likely to attract a more diverse audience will be sought.

Whilst it is unlikely that there will be significant national behavioural change stem from events such as 'A Spoonful of Soil', it is possible that the increasing attention brought about through academic scientists engaging the public, the healthcare industry and government with events such as 'A Spoonful of Soil' are slowly building momentum and changing public perception of the issue. In turn this may feed into the UK trend that has seen with regards to antibiotic prescription rates falling by 7.3% from 2014-5 to 2015-6 (Wise 2016). A fall in prescriptions requires less prescriptions to be provided by doctors but is likely driven in turn by less demand for antibiotic prescriptions by members of the public. Currently, no methodology currently exists that would enable assessment of minor events to summarise behaviour changes.

**Acknowledgements**

The authors would like to acknowledge support and resources from the Microbiology Society, Royal Society of Biology, Museum of Science and Industry, Manchester and E-Bug. Thanks are also due to all volunteers who supported the events described.

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