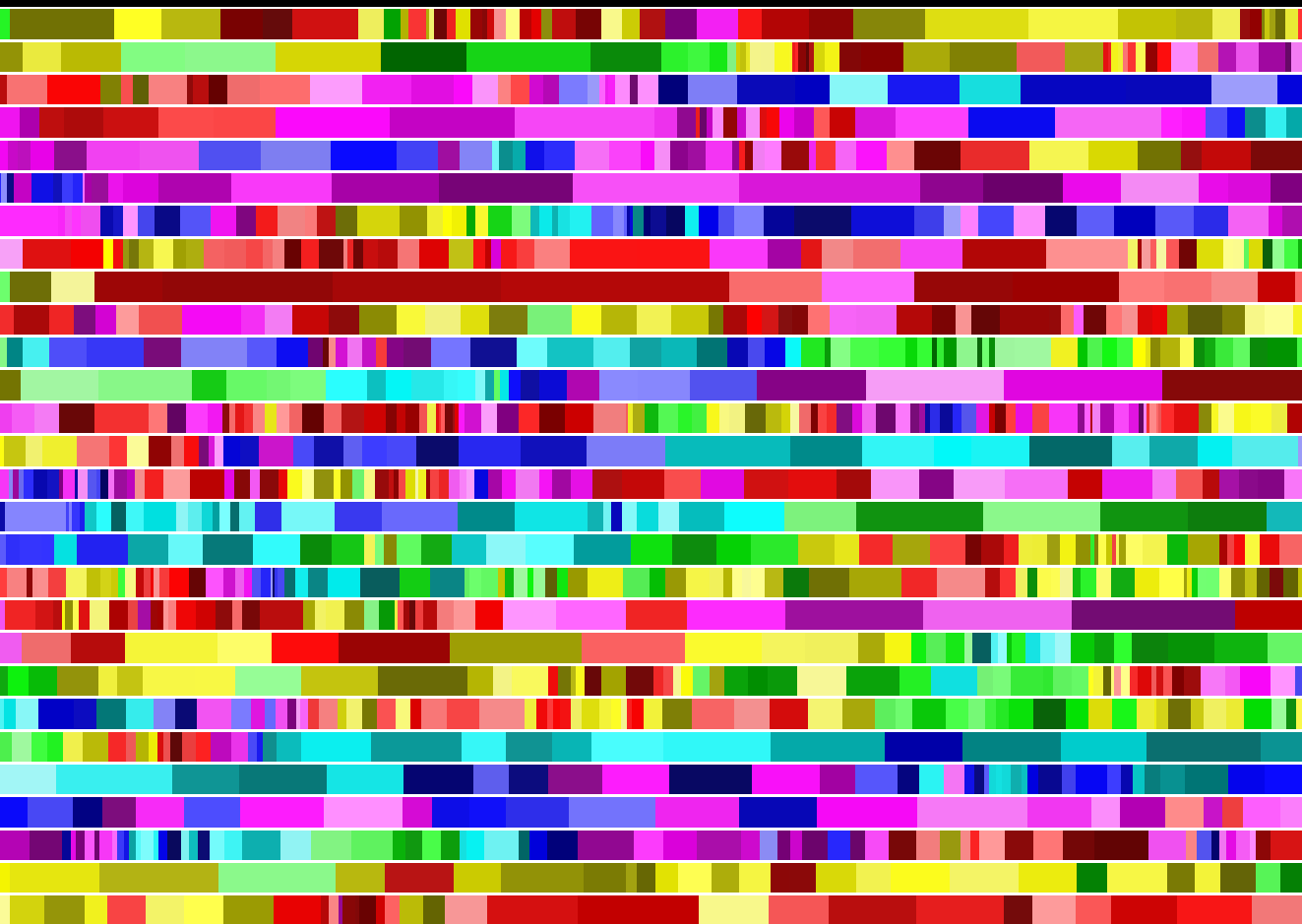


A Global Village

WHERE POLICY AND POLITICS MEET SCIENCE AND ENGINEERING



010100
110010
101111
011000

Data Explosion

Data Analytics and Privacy | Mathematics and Statistics in Finance



Waste

Energy Efficient Lighting | Radioactive Waste | Arsenic Poisoning



Global Health

Global Mental Health | Commercial Surrogacy

GLOBAL HEALTH SHORT COURSE

25 – 29 June 2012

- Who should come?** Participants who have an interest in and passion for global health and who will participate fully and contribute to debates, discussions and small group work.
- What is the format?** Lectures, small group work, interactive workshops, debates and discussions, films.
- What will it cover?** Topics will include: Why global health? An introduction to the big questions; Global burden of disease and determinants; Poverty and development; Neglected Tropical Diseases (NTDs), Zoonoses, Human Immunodeficiency Virus (HIV), Malaria; Maternal Health; Tuberculosis (TB); Local and International Global Health; Health Effects of Climate Change; Epidemics of Non-Communicable Diseases: Obesity, Diabetes, Tobacco and Environmental Hazards; Humanitarianism; Hepatitis and Hepatoma vaccines.
- Who are the teachers?** Members of Imperial College London of world-class reputation and local and international organisations, including clinicians, epidemiologists, policy experts and guest lecturers.

- Directors** Professor Helen Ward and Professor Alan Fenwick OBE
- Venue** Imperial College London, St Mary's Campus, Paddington, London
- Fee** £50. We encourage applicants from the corporate sector to give a donation in addition to the course fee, which will be put towards a hardship fund to enable participants from a variety of backgrounds to attend.
- Contact** Nikki Whitelock, n.whitelock@imperial.ac.uk
- Website** www.imperial.ac.uk/publichealth/education/shortcourses

**“When it comes to global health, there is no ‘them’
... only ‘us’”**

Global Health Council



Foreword

We live in a world where information derives power and commercial value, and can mean the difference between social control and chaos. For these reasons, governments, commercial enterprises and even the individual crave more and more information acquisition, in fact we have become consumers of information as per any other global resource. You need only consider your own social media addictions to realise that we have, as a people, become obsessed with information about our friends, families, favourite soaps, or world affairs.



What has gone largely unnoticed as a result of this cultural shift is that we have all become less sensitive to information disclosure than we have been in the past. In fact, generationally, there is a marked difference between what the current generation considers public or private information vs that of a prior generation. Hence, enhanced risk acceptance or tolerance levels have led to a much more open world of information today than that of generations before. A common example of this paradigm shift is we have come to accept, for the sake of convenience, that it is acceptable for our favourite stores to capture and manipulate information about our shopping habits, so that we may better be served as a consumer.

But with this new world of open information exchange, data collection, and expected levels of visibility about us and the world we live in comes a host of new issues related to data ownership, privacy and use of information. For instance, is it acceptable for our favourite stores to collect information on our shopping habits' and then to provide that information to a third party so that they may use it to profile our behaviour? We enter into transactional contracts with commercial entities at the point of sale and as such expect some information about us to be exchanged, but who owns that information and for what purpose may it be used under that contract? Is it possible to really own ones identity in a modern society, or are we just a single row of data in a very large database, available to be analysed by the highest bidder?

These questions way heavy on legislators and those who fight for appropriate control of information. However, when such information can be aggregated with many other information sources to provide governments with the ability to employ predicative analytics designed to highlight behavioural patterns that may be a threat to society, such as terrorism and public disorder, how can those same legislators strike the right balance between legitimate use and potential abuse? In fact, when the context of the information becomes the variable and the information itself the constant, how can it be policed appropriately, and by whom? Our information world is truly global, cross border and open, while our physical world is geo-political with legal complexities and different tolerances to what is and is not acceptable dependent on nation state. Given this reality, how can we truly police a global world without making it too easy to manoeuvre between the boundaries of the legislation?

Unlike prior generations, where today's news became tomorrow's fish and chip wrappers, we now have added complexity of the absence of a delete button on the internet. The very nature of the internet and its underlying technical architecture is such that everything is cached, if only for a few seconds. Search engines like Google offer a 'find it in our cache' feature in case the site is down, and services like the 'internet time machine' exist to create copies of content for future generations. So how do you undo that statement, or remove that photo from public view, when it is likely replicated around the globe in a few seconds? This creates a need for us to control the information we perceive to be valuable to us, and to control the flow of information as it leaves us, so that it is what we want it to be before it is consumed and analysed by the world.

This foreword has posed more questions than answers, but is done so deliberately, as these are the questions we need to consider as individuals. Only we can answer them, and only we can determine what is appropriate for our information.

Jay Abbott

Director of the Threat & Vulnerability Practice at PricewaterhouseCoopers

Note from the Editor

Remember when the year 2000 was a mythical distant future? This editor vividly recalls the thought of the millennium year as an impossibly remote and futuristic reality.

Now, more than a decade later, much of what was once the backbone of sci-fi films has become a reality. In fact, what was once life on earth seems to have morphed into a double life – an interconnected dual existence on earth and in the cyber-sphere. We have developed an insatiable thirst for information: communication is instant – and we demand access to any and all data, at any time.

A sphere of anonymous guises, free speech and free reign offers many things – it promotes creativity and unfettered expression of opinion, and but also has the potential for reckless slander and crimes committed under a thick veil of anonymity. *Prof. Chris Hankin and Andrew Burton* delve into this brave new world, and the associated security and ownership issues posed by massive data creation and assimilation.

This exponential growth in technology has contributed to an atmosphere heaving in CO₂ – but will science be able to bring us back from the brink? *Dr. Michelle Moram* tells us that next generation LEDs could significantly increase the energy efficiency of lighting sources, assisting in the reduction of CO₂ emissions resulting from electricity generation. *Palang Bumroongsakulsawat* looks at artificial photosynthesis and asks, can we turn excess CO₂ into energy in a similar manner to plants?

Fast-forward 100,000 years: what will remain of life today on earth? *Philip de Grouchy and John O’Neill* ask how can we store – and importantly signpost – toxic radioactive materials for a future civilisation?

In a time of rapid change, nothing is certain, and little is foreseeable. This issue of *A Global Village* looks at some of the emerging challenges of a generation racing to keep up.

Neave

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A Global Village

WHERE POLICY AND POLITICS MEET SCIENCE AND ENGINEERING



Submissions for the October Issue

A Global Village focuses on key areas where politics and policy meet science and engineering from global health to climate change and energy, food security and development. Article lengths should be within the range 1000-2500 words.

deadlines for issue 8

June 1

short abstract/word count

July 1

final article deadline

Key Topics: Climate Geo-Engineering, Materials, Population, Health Financing

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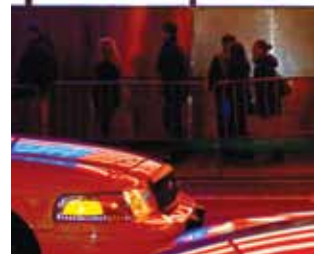
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After the Deluge: Data Analytics and Privacy

Prof. Chris Hankin & Andrew Burton, Imperial College London

The last time you logged into Amazon, were you spookily impressed that they seemed to know exactly what you were looking for? How on earth did they figure out that the latest Scandinavian crime thriller was uppermost in your mind? After all, all you did the last time was browse the latest DVD releases. But maybe you spent a little time reading the customer feedback comments, or clicked on further recommendations before deciding not to purchase. And didn't you delete those pesky cookies anyway? Welcome to the world of extremely large scale data mining, where someone, somewhere is probably keeping a very close watch on you.

It is claimed that 90% of the data in the world today has been created in the last two years¹. This explosion in data offers new opportunities but also presents tremendous challenges. The opportunities include the generation of new services to enhance quality of life (and the opportunity to pre-order the latest Lady Gaga CD). The challenges arise from the varying sources of data, uncertainty about their provenance and finding ways of extracting information/knowledge from the data and

Do I want them knowing all there is to know about me? Or maybe I don't care?

visualising it in ways which are fit for purpose. Overlaid onto these issues are those of personal choice and privacy. Do I want them knowing all there is to know about me? Or maybe I don't care?

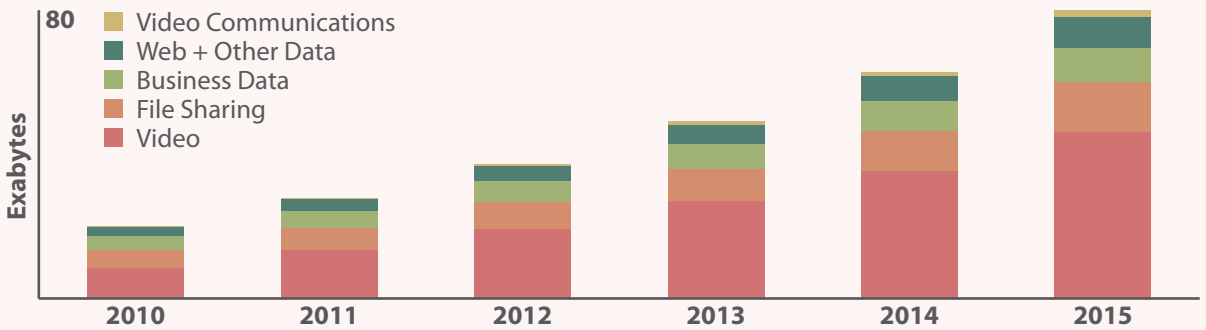
To benefit from the promise of extensive machine intelligence, a brave new world of pervasive data has set upon us. The capture of more and more data makes predictions more accurate and informative, enabling more accurately tailored and hence responsive services. But if we wish to live in a carefree world with such automated convenience, it will only come about through mining private data ... and in huge quantities.

Of course, data collection is one thing but information and thence knowledge and understanding are quite another. Throughout history, and latterly through scientific disciplines, mankind has sought to make sense of its surroundings. In recent times this physical surrounding has moved into the virtual or cyber world, presenting massively enlarged data spaces beyond what could be captured, processed and recorded in previous times. The cyber world now contains all sorts of data including virtual manifestations of physical reality, as well as some that are unique to cyber space.

- [1] IBM (2012) Bringing big data to the enterprise [online] Available at: <<http://www-01.ibm.com/software/data/bigdata/>> [Accessed 18 March 2012].
- [2] Thomas J. J. & Cook K. A. (2005) Illuminating the Path: The Research and Development Agenda for Visual Analytics. Washington: National Visualization and Analytics Center.
- [3] The National Visualization and Analytics Center (<http://nvac.pnl.gov/>).
- [4] Visual Analytics for Command, Control, and Interoperability Environments. (<http://www.purdue.edu/discoverypark/vaccine/>).
- [5] Command, Control, and Interoperability Center for Advanced Data Analysis (<http://ccicada.org/>).
- [6] The UK Visual Analytics Consortium (<http://www.eis.mdx.ac.uk/research/idc/UKVAC/Index.htm>).



Monthly network IP traffic is forecasted to grow to 80 Exabyte/month by 2015. (Voice communications and online gaming negligible; 1 Exabyte = 1018bytes; Source: Cisco Visual Networking Index¹⁴)



Visual Analytics

UK government interest in the data explosion can be traced back to the late 1990s when the anticipated arrival of the Large Hadron Collider (LHC, now operational at CERN and homing in, possibly, on the Higgs boson) provided one of the motivations for the Research Councils' e-Science programme. In the security context, the myriad of data that supported the post-9/11 terrorist investigations led the newly formed US Department of Homeland Security (DHS) to sponsor the emergence of the new discipline of Visual Analytics. Most recently (late 2011) the Engineering and Physical Sciences Research Council (EPSRC) together with the UK Ministry of Defence (MoD) launched a call for proposals to address Data Intensive Systems.

The call identified three core topics: (1) extracting meaningful information; (2) safe and secure cloud computing – anticipating that much of the data handling will be in the cloud; and (3) ensuring confidence in collaborative working – given that the processing of 'big data' is likely to necessarily involve cooperative working.

Visual Analytics (VA) is the science of making sense of large data sets that, through the use of interactive visualization and query through semantic extraction and data fusion technologies, support the analytic reasoning process. The roadmap for research in this area was established in 2005². Activity in the US has been orchestrated through the National Visualization and Analytics Center³ which has engaged universities through the DHS academic Centres of Excellence at Purdue University (VACCINE⁴)

and Rutgers University (CCICADA⁵). Since 2009 this activity has included an international collaborative effort with a UK consortium, UKVAC⁶, of which the Institute for Security Science and Technology (ISST) at Imperial College is a founding partner.

VA is the use of interactive visualizations to support the human analytic reasoning process, with tools that facilitate dynamic query, analysis, hypothesis formulation and testing, collation and marshalling of evidence for sense-making (colloquially referred to as 'joining the dots'). VA also requires strong algorithms for 'smart' information retrieval, extraction, and concept searching, and new data structures to support data handling, provenance, ad-hoc querying and methods for handling missing data and uncertainty. VA provides the framework for combining data, visualization and human sense-making aspects to create integrated workspaces for analysts.

At ISST, we concentrate on the data analytics components of VA. We are dealing with data that is incomplete, sometimes unreliable and internally inconsistent; it is a mix of data that includes structured and unstructured text, still and video images, audio feeds and computer media. We are developing new algorithms for abstracting the data and analysing relationships in the data. For example, one abstraction is based on clustering and leads to algorithms for detecting sub-communities. It is then possible to study how these evolve and try to identify which external triggers cause individuals to migrate between communities.

With the threat of a surveillance society hanging over us, the challenge is to balance the protection of the state with the protection of civil liberties.



Policing Cyberspace – The Surveillance State?

In the national security context, VA could be used, legitimately by authorities under warrant, to tap into private communications and databases as part of intelligence gathering for countering crime and terrorism. But access needs to be tightly controlled. In the UK this has been written into law through RIPA (the Regulation of Investigatory Powers Act 2000), which sets out the law regarding intercept and surveillance, and the limitations on the authorities on what can be gathered and the use to which it can be put.

The massive increase in cybercrime has demanded that police forces establish the capability to respond to what is already taking the form of an on-line arms race. Are the current measures adequate?

In the UK, the Metropolitan Police Service is host to the Police Central E-Crime Unit (PCeU) which investigates and prosecutes on-line crime, but often runs headlong into foreign jurisdictions. This necessitates global agreements to tackle criminals who seamlessly straddle national boundaries. Digital forensics capability has also required a boost in capability and capacity: first finding and retrieving data behind the multitude of cloaking methods readily available before processing it in a manner suitable for presentation to a court of law, following accepted standards for evidence preservation.

Reality Mining goes beyond the digital footprint idea ... and into a much finer grained data space, a digital dust comprised of almost every instance of a person captured by electronic means.

But policing the internet has to take into account its very soul, the privacy and liberty which are essential to the free flow of ideas. Those concerned with civil liberties question the role of secret intelligence in an open society. As Brill (played by Gabriel Byrne) in the Hollywood film *Enemy of the State* (1998) says: “How do we draw the line – draw the line between protection of national security, obviously the government’s need to obtain intelligence data, and the protection of civil liberties ...”

This is a question which is worthy of some debate. With our increasing abilities to automatically mine and analyse huge quantities of data, it is not only governments but also big corporations and even other individuals who want to derive value from using our data (assuming, of course, that we can regard it as ours). This is most often for commercial advantage yet, with the threat of a surveillance society hanging over us, the challenge is to balance the protection of the state with the protection of civil liberties.

The quote from Brill continues: “... particularly the sanctity of my home? You’ve got no right to come into my home!”

Yet the European Electricity and Gas Directives⁷ mandate the deployment of smart meters in every domestic setting by 2022. Each of those will publish half-hourly read-outs of energy consumption to the energy provider but will be capable of much greater data gathering.

One of the earliest attempts to gather and operate on big data was the US programme for Total Information Awareness⁸ (TIA, which might be viewed as an attempt to realise the fictional capability depicted in *Enemy of*

[7] The European Union Gas and Electricity Directives (http://gala.gre.ac.uk/3629/1/PSIRU_9600_-_2005-10-E-EUDirective.pdf).

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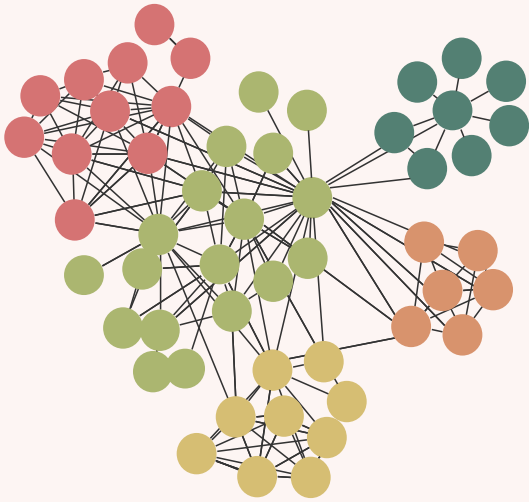
[10] MIT (2009) Reality Mining, Machine Perception and Learning of Complex Social Systems [online] Available at: <<http://reality.media.mit.edu/>> [Accessed 18 March 2012].

[11] Imperial Dept of Computing (2009) Intelligent Behaviour Understanding Group, Social Signal Processing [online] Available at: <<http://ibug.doc.ic.ac.uk/research/social-signal-processing>> [Accessed 18 March 2012].

[12] Bizreport.com (2010) AVG: Children have online presence before birth [online] Available at: <<http://www.bizreport.com/2010/10/avg-children-have-online-presence-before-birth.html>> [Accessed 18th March 2012].

[13] European Commission (2012) Data Protection Day 2012: Safeguarding online privacy rights through modern data protection rules [online] Available at: <http://ec.europa.eu/commission_2010-2014/reading/multimedia/news/2012/01/20120124_en.htm> [Accessed 18th March 2012].

[14] Cisco Virtual Networking Index (2011) Forecast and Methodology, 2010-2015 [online] Available at: <http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360_ns827_Networking_Solutions_White_Paper.html> [Accessed 18th March 2012].



Community Detection

The use of sense-making tools for the analysis of large datasets is under investigation by researchers in the Institute for Security Science & Technology. Community detection is the term given to uncovering the structure of networks in organised crime and terrorism investigations. The example described takes its data from Victor Hugo's *Les Misérables*. A partitioning algorithm based on the technique of stability optimisation results in the detection of five communities amongst the 77 characters in the novel. This example shows a main community at the centre that seems to connect all the story while satellite communities represent sub-stories. If this was a network of people under surveillance it would reveal a main community of central actors which could be observed over time.

the State.) The TIA program set out, in similar fashion to VA, to better detect terrorist operations and to inform US agencies' responses. The vision was for an 'architecture' capable of integrating many other program outputs, which crucially attempted to predict events (incorporating social sciences) rather than simply respond post-event. Despite the acronym being redefined as Terrorist Information Awareness due to much adverse publicity (particularly the issue of intrusion and compilation of dossiers on hundreds of millions of American citizens), the program was terminated in 2003. Nonetheless, TIA elements are largely to be found in current R&D programs funded through DHS, the Department of Defense and others⁹. Visual Analytics could be regarded as a direct descendent.

How would you feel if a speeding ticket arrived in the post based on measured GPS coordinates from your own smart phone?

The modern face of TIA is Reality Mining¹⁰, an increasingly referenced emerging technology defined as the collection of machine-sensed environmental data pertaining to human social behaviour. Reality Mining goes beyond the digital footprint idea (i.e. the collection of information left behind as one navigates cyberspace through on-line activity such as social networking, email, e-commerce, etc) and into a much finer grained data space, a digital dust comprised of almost every instance of a

person captured by electronic means (e.g. adding CCTV, online photo archives, etc).

The key ingredient in Reality Mining, as it seeks to predict human behaviour, is to factor in the new discipline of Social Signal Processing¹¹, this is to enable automatic recognition and interpretation of our non-verbal behaviour as a basis for the creation of a socially sensitive machine. But, at its heart, Reality Mining, despite its benign promise in areas such as predicting the spread of disease based on networks of infection, relies on the collection of enormous amounts of deeply personal information, for example by employing pervasive technology such as always-on smart phone cameras and accelerometers. This raises quite naturally the question of protection of our data from those who may wish to use it for other means. Facebook users already need to be careful about broadcasting their holiday plans (for fear of home burglary), but how would you feel if a speeding ticket arrived in the post based on measured GPS coordinates from your own smart phone?

The Right to Privacy

Much has been said, recently, about the growing awareness of individual privacy, with social media tools now seeking to offer more flexibility in privacy setting options for a more informed consumer. But, how much of your personal data are you actually leaving behind as you navigate cyber space? A 2010 survey by internet security company AVG¹² found that 35% of newborns had an



A 2010 survey by internet company AVG found that 35% of newborns already had an online presence

online presence (email, social media, photos, etc), with 23% having a prenatal presence through their parents' uploading foetal scans to the web.

So what can an individual do if they wish to be 'forgotten'? The European Commission is getting into the act, tabling an amendment to Directive 95/46/EC on the protection of individuals with regard to the processing of personal data and on the free movement of such data¹³. Included in the proposed amendment would be the ability of a person to have their personal information deleted including, for example, any photograph of them held on a social networking site. The sanctions for non-compliance could be astronomical with millions of Euros in fines being levied. This offers a severe challenge for data handling organisations, whether in government or in the private sector, and especially as such data is hosted more and more within a cloud service environment.

As the Vice President of the European Commission, Viviane Reding, said on introducing the draft amendment to the Directive: "The protection of personal data is a fundamental right for all Europeans, but citizens do

not always feel in full control of their personal data. My proposals will help build trust in online services because people will be better informed about their rights and in more control of their information ... A strong, clear and uniform legal framework at EU level will help to unleash the potential of the Digital Single Market and foster economic growth, innovation and job creation."

In the era of cloud-based computing services, can anyone to be truly certain that their request for deletion has been enacted?

The amendment to Directive 95/46/EC must be ratified by member state parliaments, and it is too early to say whether this Europe-wide legislation will become a reality. In essence the legislation will streamline data protection rules so that companies need only deal with data protection agencies in their home country (at present the Commission claim that billions of Euros are wasted in cross border compliance). As with all laws, unless it can be policed it will be meaningless. In the era of cloud-based computing services, can anyone be truly certain that their request for deletion has been enacted? The recent announcement by Google of its new privacy policy – enabling it to aggregate data from all its products, thereby increasing its 'collective knowledge' of users who have no option to opt out short of not using their products – may test the new legislation.

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Prof. Chris Hankin is Director of the Institute for Security Science and Technology (ISST) and a Professor of Computing Science at Imperial College London.

Andrew Burton joined the ISST in 2008 as Programme Manager, having previously worked with the Ministry of Defence.

Mathematics and Statistics in Finance

Prof. David Hand FBA, Imperial College London

Finance has always been built on mathematics. For example, in his book *Summa de Arithmetica*, Luca Pacioli, born in 1445, described the double-entry bookkeeping system through which merchants have controlled their businesses over the past half-millennium. Incidentally, Pacioli was a personal friend of Leonardo da Vinci – they once shared a house in Florence and drawings by da Vinci appear in Pacioli's book *Divina Proportione*.

Mathematical models for finance evolved radically from about 1900, when Bachelier applied Brownian motion as an underlying process to derive option prices. Since then the use of probability theory and partial differential equations has boomed, to the extent that Merton and Scholes were awarded a Nobel Prize in 1997 for the contribution of mathematical finance to global economics.

Today banking systems, credit card operations, pension funds, and insurance companies amongst many others rely on such models to make decisions about all manner of financial transactions. As has been highlighted in recent years, the risk is that, while those developing these sophisticated models may understand them perfectly, those basing their decisions on them may not.

Nowadays, both finance and mathematics have grown into vast edifices, but they continue to be closely interwoven. Mathematics – or, more accurately, the mathematical disciplines – have a diverse, and it is no exaggeration to say fundamental, role to play in many

quite different aspects of finance. This article singles out just three aspects: (i) so-called 'mathematical finance' (ii) hedge funds, and (iii) retail financial services.

Rocket Science

The first of these, mathematical finance, is concerned with building financial instruments for investment, and controlling risks: designing such things as financial options and derivatives. Through such instruments merchants can protect themselves from risk (e.g. by agreeing to buy raw materials in the future at a specified price, so protecting themselves from unpredictable price changes), and traders can seek to make money (e.g. if the price of the raw material in fact falls over the intervening period, by buying at the new reduced price and simultaneously selling at the agreed price).

This area uses advanced mathematics such as stochastic differential calculus and measure theory. It has been described as one of the few areas where cutting-edge mathematical research has a direct and immediate impact in a practical area. The nature of the mathematics involved in this area explains why it attracts physicists (the same equations describe the evolution of some physical systems and some financial systems), and hence why the phrase 'rocket science' has sometimes been attached to it.

A characteristic of this area is that it has, in the main, been built on economic models of the financial system. The efficient market hypothesis is important in

The effectiveness of work in this area hinges on how accurate the models are, and how effectively they are used.

this area. This says that it is impossible to produce a trading strategy (a strategy for buying and selling financial products) which outperforms the market (except randomly) because any information indicating that a particular stock is over or under-valued is already taken account of in the stock's price. Despite its importance in some areas, the efficient market hypothesis is not an uncontroversial idea, and some people do seem able to outperform the market with a consistency beyond that suggested by chance. But it is clearly almost true – which is why outperforming the market is so hard. A classic book in this area (and there are a great many) is Hull (2009)¹.

The effectiveness of work in this area hinges on how accurate the models are, and how effectively they are used. In particular, if they are based on shaky premises then there are clearly unquantified risks. The well-known collapse of Long Term Capital Management² arose as a consequence of a failure to take into account the fact that perhaps there would not always be buyers and sellers willing to take the other side of a trade. The sub-prime crisis was based on perfectly sound mathematical models but if, despite the fact that your model tells you an applicant for a mortgage has a high risk of defaulting on the repayments, you go ahead and make the loan, you cannot really blame the mathematics.

Furthermore, the models in this area are highly, and increasingly, sophisticated. There is a real risk that while those developing the models may understand them perfectly, higher management may not, with obvious dangers. By way of illustration, the Turner report³, which describes the events leading up to the recent financial crisis, chooses its words carefully: it does not ask ‘was the mathematics wrong?’, but asks was there ‘misplaced reliance on sophisticated mathematics?’ That is, did those who bore the ultimate responsibility for deciding to use the models really know what they were doing? These aspects are discussed in Hand (2009)⁴, but to put things into context, the excellent and informed review by Reinhart and Rogoff (2009)⁵ examines the history of financial crashes over several

centuries (with some wonderful data!), from long before sophisticated mathematical models were available.

Hedge Your Bets

The second area listed above was that of hedge funds. In fact, the phrase ‘hedge fund’ is not a well-defined concept, as it covers a very wide range of quite distinct kinds of trading activity. Some base their trading strategies on perceived fundamental value of the stocks being traded, others use subjective views on how the market is behaving, others are based on objective statistical models of price time series, and so on. Investors in hedge funds are constrained by regulation, but typically include pension funds, university endowments, and high net worth individuals, but not the public.

Hedge fund managers usually have their own money invested in their funds, so aligning what they do with what their customers want. This need not be the case with banks, where the aims of customers and shareholders might not be aligned. Most hedge funds seek an absolute return, a positive return on investments, regardless of whether the market is going up or down. Hedge funds are a relatively recent development, beginning in about the 1960s. An entertaining history of hedge funds is given by Mallaby (2010)⁶.

One class of hedge funds is based on ‘systematic trading’: the use of mathematical and statistical models to predict market behaviour and make trading decisions with little or no human intervention. In contrast to the models of the financial mathematicians, described above, the models used in these organisations are empirical models, based on intensive statistical analysis of past behaviour of the financial markets. Some com-

The Turner report ... chooses its words carefully: it does not ask ‘was the mathematics wrong?’, but asks was there ‘misplaced reliance on sophisticated mathematics?’

- [1] Hull J. C. (2009) *Options, Futures, and Other Derivatives*. 7th ed. Pearson Education Ltd. London.
- [2] Lowenstein R. (2002) *When Genius Failed*. Harper Collins, London.
- [3] Turner A. (2009) *The Turner Review: a regulatory response to the global banking crisis*. Financial Services Authority.
- [4] Hand D. J. (2009) Did over-reliance on financial models for risk assessment create the financial crisis? *Foundation for Science and Technology Journal*. 20: 28-29.
- [5] Reinhart C. M. and Rogoff K. S. (2009) *This Time Is Different*. Princeton University Press. Princeton.
- [6] Mallaby S. (2010) *More Money Than God*. Bloomsbury Publishing. London.



The 2011 film Margin Call saw Kevin Spacey play an embattled finance executive, struggling to grasp the complexities of the algorithms his traders were employing daily on the floor

mentators have expressed concerns that if many hedge funds adopt similar strategies, then the correlation between the way they behave will introduce instabilities into financial markets – and have attributed the so-called ‘quant quake’ of 2007 to this cause.

You will have noticed the use of the phrase ‘mathematical and statistical models’ above, and the distinction made between mathematics and ‘the mathematical disciplines’. Although statistics is often taught in mathematics departments, the two disciplines are rather different, and few statisticians nowadays regard their discipline as a part of mathematics. Certainly statistics has mathematics at its base, as do physics and engineering, for example, but statistics is no more a part of mathematics than are those disciplines. In particular, the discipline of statistics has been revolutionised over the past fifty years by the development of the computer, so that one might, with equal justification regard statistics as a part of computer science.

Although statistics is often taught in mathematics departments, the two disciplines are rather different ... one might, with equal justification regard statistics as a part of computer science.

The key point is that statistics starts with the question and the data, and seeks to apply formal methods of inference to find structures and relationships, and to extract understanding and meaning. Mathematics, in contrast, is fundamentally concerned with deduction about given abstract objects and their relationships. This, in fact, is a commonly made distinction between probabilists and statisticians: the former start with the mathematics, and try to deduce what the data would look like; the latter begin with the data, and try to work out what kind of structure would have generated it. This explains the opening comment of the preface of David Williams’s marvellous book *Weighing the Odds*⁷: ‘Probability and Statistics used to be married; then they separated; then they got divorced; now they hardly ever see each other.’

Data Crunching

That small detour serves as an introduction to the third area mentioned at the beginning: the retail financial services sector. Retail banking or consumer banking refers to the sorts of transactions in which you and I



Some hedge funds base their trading strategies on perceived fundamental value of the stocks being traded. Others use subjective views on how the market is behaving, or base trading decisions on objective statistical models of price time series

engage every day. It covers such things as credit and debit cards, mortgages, car finance, personal insurance, store cards, personal loans, and so on. And it will be immediately obvious that one of the characteristics of this area is that it involves large, even massive, data sets. Many organisations in the sector carry out billions of transactions each year. So, in this area, we are really talking about statistics rather than mathematics.

The aim in this area is to build models of how people behave so that one can answer a variety of questions: will an applicant for a loan make the scheduled

repayments on time; is the owner of a credit card running into financial difficulties; is that anomalous credit card transaction evidence of fraud; is that pattern of mortgage applications suggestive of something suspicious? Anderson (2007)⁸ gives an introduction to the area.

Almost universally, the models in this area are empirical models. That is, the models are not based on any underlying theory (e.g. from the psychology of behavioural finance) but are entirely data driven. A characteristic will be included in a model if the data analysis shows that it leads to improved prediction, regardless of whether there are theoretical reasons which might lead one to expect it to be predictive.

That last sentence should be slightly qualified. Such a characteristic will be included only if legal restrictions allow it (e.g. the US Equal Credit Opportunity Act of 1974). Typically, anti-discrimination legislation

Statistical algorithms ... far outweigh anything that a human could do: they make more accurate decisions

[7] Williams D. (2001) *Weighing the Odds*. Cambridge University Press. Cambridge.
 [8] Anderson R. (2007) *The Credit Scoring Toolkit*. Oxford University Press. Oxford.
 [9] Hand D. J. (2012) Credit scoring, insurance, and discrimination. To appear in Proceedings of the Conference on Statistics, Science and Public Policy XVI: Risks, Rights and Regulations. April 17-20, 2011.

precludes certain characteristics, such as sex, race, colour, and religion, from being included in these so-called credit scorecards.

The models in this area have increased in sophistication since they initially began to be introduced in the 1960s, concurrently with the advent of the computer. Initial scepticism about whether statistical algorithms could be as accurate in their decision-making as human beings soon gave way to a recognition that they could. Since then, decades of research and refinement, coupled with the growth of massive databases, now means that such systems far outweigh anything that a human could do: they make more accurate decisions.

The models can be very elaborate. They often take the form of logistic regression trees, in which the population is divided into subgroups, with a distinct logistic regression model being built in each segment. They may involve hundreds of variables.

An important area of work in this area is the evaluation of the scorecards. This is because the domain is characterised by so-called population drift: changes in the nature of the population of people applying for or using the financial products arising from changing economic conditions (e.g. making people less willing to take out loans), changing competitive environment (e.g. often because globalisation encourages international competition or because non-finance players, such as supermarkets, enter the financial arena), or changing technology (e.g. the advent of internet banking, and more recently mobile phone cash transfers).

To illustrate just one of the difficulties, imagine deciding that a loan scorecard's performance has degraded, so that one wishes to construct a new one. The available data will be the descriptive characteristics of those who sought a loan in the past, along with the outcome (e.g. whether they defaulted or not) of those who were previously given a loan. But this is not the population to which the new model will be applied: we wish to calculate a creditworthiness score for all applicants, not merely those that the old method would have

accepted. Thus we have a distorted population from which to build a new model. Coping with such selection bias is a non-trivial problem – to the extent that James Heckman was awarded the 2000 Nobel Prize for Economics for his efforts to tackle it.

Another conceptual and methodological challenge in this area is posed by the legal constraints on allowed characteristics mentioned above. This is described in more detail in Hand (2012)⁹ but the essence of the challenge is as follows, illustrated for the case of a loan. Sex cannot be included in scorecards because gender, per se, is irrelevant to propensity to repay, and one would not want to base decisions on prejudice.

But, in general, women are lower risks than men, so that this exclusion means that women are being forced to pay a higher rate than men. Roughly speaking, the solution to the problem is to construct a scorecard using all the predictive characteristics one can find, so that one's estimate of the probability of failing to repay is the most accurate estimate one can get, but then to base one's decision on the model excluding the prohibited variables. This leads to a decision which includes that aspect of gender which is predictive of default probability, but excludes all other (irrelevant, prejudiced-based) aspects.

As illustrated above, the range of interaction between the mathematical disciplines and finance is large, spanning a number of different kinds of application domains. What is common, however, is that as time progresses, all of these areas are requiring an ever higher level of mathematical and statistical sophistication. It would be quite impossible to run a banking system, credit card operation, pension fund, insurance company, or other financial operation without mathematical and statistical tools right at the heart of the enterprise.

Sex cannot be included in scorecards because gender, per se, is irrelevant to propensity to repay, and one would not want to base decisions on prejudice. But, in general, women are lower risks than men

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China's Digital Generations: The Online Empire

David Michael, Christoph Nettesheim & Yvonne Zhou, The Boston Consulting Group

China may still be classified as an emerging market, but on the Internet it has arrived. By 2015, China will add nearly 200 million users, reaching an Internet population of more than 700 million – almost double the combined number of Japan and the US.

If not by 2015, then shortly thereafter, China will likely become the largest online retail market in the world, with close to 10% of retail sales occurring online.

While China is a huge online market, it is not an easy one. Although consumers are rapidly gaining sophistication, they have their own patterns of online consumption and behaviour that are different from those of consumers in the West.

The Boston Consulting Group has regularly tracked the evolution of China's digital consumers since 1998, and this report is the latest in our series chronicling the epic transformation of China's consumer landscape. Companies that want to succeed in China's consumer market must understand both these new consumers and their rapidly evolving digital lifestyles. They also need to learn how to reach, sell to, and retain these consumers as they create the world's most important consumer market of the future.

In 2011, Chinese consumers spent 1.9 billion hours a day online – an increase of 60% from two years earlier. Far from crimping the expansion of the Internet, the government is encouraging its growth. During the current five-year plan, which runs through the end of 2015, the government has committed to spending \$250 billion on broadband infrastructure.

As the quality of infrastructure improves, the Chinese will be surfing the Web more often at home and at work and less often at Internet cafés. They will also be relying on their mobile phones.

The Changing Face of the Internet

It is crucially important for companies that want to reach consumers in China to understand them on their terms and not impose mental maps drawn from other markets. In previous analysis on China's digital generations¹, we relied on six segments, based on income and age, to provide that perspective. Those six segments are still valid but do not accommodate rapid recent growth among older generations and rural residents. Accordingly, we have added a rural and a senior segment.

In 2011, Chinese consumers spent 1.9 billion hours a day online

The Internet in China continues to be dominated by entertainment, especially video. But there is growing usage in e-commerce, community-oriented, and information activities.

The eight segments, however, do not participate in these activities equally.

Younger users tend to spend more time online but, other than young professionals, are not yet spending large sums of money online. Middle-aged users spend less time online than their younger peers, who grew up with the Internet. The willingness of middle-agers to experiment online rises with education. Although seniors and rural residents have been largely overlooked and are newer to the online world, they are rapidly making

[1] Michael, D. C. & Zhou, Y. (2010) China's Digital Generations 2.0: Digital Media and Commerce Go Mainstream. The Boston Consulting Group.

the Internet a part of their lives. Rural residents will contribute more than one-third of the Internet's growth between 2011 and 2015 – a rate faster than between 2008 and 2011. The urban senior segment will likely grow by 22% annually between 2011 and 2015, making it the fastest-growing segment.

Over the four years that we have tracked the digital generations in China, many Internet users have moved from one segment to another or migrated to more sophisticated activities within a segment. The Internet is becoming entwined with routine activities at work and at home. While the eight segments help to illuminate the differences within China, the Internet has the power to draw the sprawling nation together, by both serving as a soapbox for a national conversation and extending companies' commercial footprint.

The Power of Digital Dialogue

Blogging and microblogging have higher penetration rates among Internet users in China than among those in the US or Japan. Sina Weibo was launched in June 2009, after the government blocked Twitter and Fanfou, a Twitter clone. Since then, the service has grown both virally and through clever marketing. Sina Weibo has encouraged celebrities in business, show business, and the media to join, and some of them have attracted tens of millions of followers.

Weibos have become a fast-moving stream of collective consciousness. While controversy and complaints may receive the most attention, especially in the Western media, celebrity gossip is a more common form of currency. Users also post news stories, exchange photos with former classmates, and comment on recent purchases.

This wellspring of opinions is forcing companies and the government to respond. While the role of weibos in the overall marketing landscape is still evolving, companies at least need to be able to respond swiftly and decisively when their products and services are called into question on microblogging sites and elsewhere online.

Besides crisis control, companies ought to be examining how and when they can harness the power of online conversations to burnish their brands. Vancl, an online clothing retailer, has been especially successful at this

approach, which is explored later in the article. Positive commentary about products and services, in other words, can go viral just as easily as gossip and news about catastrophes.

Even the government is getting into the act. As of October 2011, government agencies across all 34 provinces had created nearly 20,000 weibo accounts. Police agencies have cracked cases with the help of clues provided through weibos. Nanjing, a city of 5 million in eastern China, has started to post air quality readings on Sina Weibo.

Environmental activists have begun to post daily or even hourly readings of air quality in China's pollution-draped cities. The publicity generated by these readings has forced the government to revise its policies on collecting and publicizing air quality data in a nation where hundreds of thousands of premature deaths are attributable annually to air pollution.

When it comes to conversation, it is hard to put the genie back into the bottle. In late 2011, the government announced that people must start using their real names to open weibo accounts. The jury is out on whether the new rule will slow, change, or deflect the conversation.

The Fast and Furious E-Commerce Market of China

As their comfort level and sophistication have grown, users have branched out from entertaining themselves to a more diverse mix of activities including those they once avoided, notably e-commerce.

In the past two years, Chinese consumers have opened their wallets and pocketbooks online. Online buying and selling is, including group purchasing (through Chinese equivalents of Groupon) the second-fastest-growing activity, after microblogging. The country has 193 million online shoppers – more than even the US with 170 million, and five times that of the UK. Between 2011 and 2015, per capita online spending will likely rise by 15% annually, more than doubling the expected overall increase in consumer spending and reflecting both the rising level of trust by consumers and the greater protections put in place by merchants. E-commerce's share of total retailing could reach 8% by 2015.

Rural residents will contribute more than one-third of the Internet's growth between 2011 and 2015

| | Teenagers | University students | Young professionals | Young seekers | Active middle-agers | Moderate middle-agers | Seniors | Rural residents |
|---------|---|--|--|--|--|---|---|--|
| Age | 12-18 | 19-25 | 26-35 | 26-35 | 36-50 | 36-50 | 51+ | 12+ |
| Basics | Grew up with the internet | Grew up with the internet | Educated and middle class | Lower education and income | Middle class and familiar with the internet | Lower education and income | Grew up without the internet | Lower education and income |
| Motives | Fun and study | Maintain social connections | Make work, life, and play easier | Excitement and achievement | Support in daily activities | Relaxation and fun | Stay in touch with family | Entertainment and diversion |
| Usage | <ul style="list-style-type: none"> • Light • Videos and IM (instant messaging) • Willing to try new activities | <ul style="list-style-type: none"> • Light • Videos, IM, and weibo | <ul style="list-style-type: none"> • Heavy • Wide usage across the board | <ul style="list-style-type: none"> • Heavy • Videos, games, IM, and e-commerce | <ul style="list-style-type: none"> • Moderate • Videos, news, and e-commerce | <ul style="list-style-type: none"> • Light • Videos, news, and IM | <ul style="list-style-type: none"> • Light to moderate • Videos, news, and IM | <ul style="list-style-type: none"> • Light • Videos, games, and IM |

Eight ways to segment the internet (Source: BCG survey of 2,000 consumers from first- to fourth-tier cities and rural areas; BCG analysis)

Maturity means that future growth of the user base will slow. China's Internet population is expected to increase by 8% annually between 2011 and 2015 – one-half the annual rate of the previous two years. However, opportunities will continue to expand, even as user growth flattens.

One of the key challenges for companies is to encourage their customers to shop online, because, our research shows, once they make the leap, they quickly become

avid Internet shoppers. In focus groups, consumers who had devoted only 5% of their spending to the online channel in 2008 said they had increased the share to more than 50% by 2011. Twenty-five per cent of consumers research online before buying offline – almost as many as the 29% who both research and buy online.

E-commerce in China has developed its own personality. While there are analogues to Amazon and eBay in China, the nation is not on a parallel track to the US or anyplace else. There are three main types of commercial activity:

Marketplaces. Consumer-to-consumer and business-to-consumer marketplaces are frequently compared to eBay and Amazon Marketplace but have their own local

flavour. Alibaba Group currently dominates consumer e-commerce in China through its Taobao consumer-to-consumer and Tmall business-to-consumer sites. More products were purchased on Taobao in 2010 than at China's top five brick-and-mortar retailers combined, with 48,000 products sold per minute.

Taobao has worked hard to achieve this scale. It has developed extensive data-analytics capability in order to understand buying and usage patterns, created an in-house university to allow merchants to share best practices, and developed an instant-messaging system that allows buyers and sellers to share product information.

Business-to-Consumer Vertical Sites. 360buy.com is the second-largest business-to-consumer site in the country, after Tmall, and the largest that sells inventory directly to consumers. The company received a \$1.5 billion cash infusion in 2011 from private investors, including Russia's Digital Sky Technologies – one of the largest institutional investors in Facebook. It is putting the investments to work in building customer-service and logistics operations. The company is also focused on making the customer experience easy and satisfying.

Positive commentary about products and services ... can go viral just as easily as gossip and news about catastrophes

Besides offering cash-on-delivery payment, a simple Web interface, and a guarantee of product quality, it pledges that if a customer complains about a product, a delivery person will return within 100 minutes to take it back.

Business-to-Consumer Brand Sites. Vancl is the largest business-to-consumer brand site in China through several innovative online approaches to generate sales and engage with customers. The company has been an active advertiser. In 2008, the year it was founded, Vancl's advertising budget was nearly as large as its revenues.

The company also has an active presence on Sina Weibo. The chief executive, designers, and regular employees all write posts, and the company encourages fan clubs to form and discuss clothing on Sina Weibo. As part of its weibo strategy, Vancl has offered free merchandise to celebrate Chinese Valentine's Day. To encourage customer engagement, Vancl created its Star program. Customers post photos of themselves modeling Vancl clothing, and other users get to vote.

Capturing the Online Empire

A disconnect currently exists between how Chinese consumers spend their time and how advertisers spend their money. Advertisers have begun to increase their online spending, but the mix is still heavily skewed toward traditional media.

But the broader focus in China should be on what all companies are doing to reach and hold on to China's digital generations. The Internet is not just another channel. A few key challenges confront companies as they sell to engage with China's digital generations.

New business models based upon consumer insight. Companies cannot necessarily rely on what has worked in other markets, as the stumbles of many Western companies have amply demonstrated. But they can tap into the current fascination of the Chinese people with the online experience to experiment with new ways to build relationships with Chinese consumers. In particular, the popularity of weibos and online videos presents opportunities to both engage with customers and develop new revenue streams through innovative online business models.

Channel management. The channel conflicts that companies face in the West are magnified in China because of the resale of their goods on online marketplaces. Companies do not completely control the destiny of their own products. Most companies in China have barely started to explore the potential of the mobile channel. Companies need to try to develop a coherent channel strategy and build the systems to trace sales through multiple channels.

360buy.com pledges that if a customer complains about a product, a delivery person will return within 100 minutes to take it back

Companies need to create an integrated digital-marketing plan that emphasizes online presence and dialogue with consumers. They will have to regularly review the alignment between

marketing mix and consumer trends. They must monitor and respond to online conversations about their products and services, engaging and building relationships with consumers.

A Call to Action

China has become a major Internet market with increasingly sophisticated consumers. Companies that want to win in China's consumer market must understand both these new consumers and their rapidly evolving digital lifestyles.

To do this, they need to understand how they experience the Internet in their daily lives. Online buying and selling, including group purchasing, is the second-fastest-growing activity after microblogging.

Companies with ambitions in China should have a strong Internet presence and strategy. They need to meet their customers in the places where they spend time, and increasingly that is online.

Companies cannot win in China unless they understand and embrace China's digital generations. They are the future of the largest consumer market in the world.

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Lighting up Lives with Energy Efficient Lighting

Dr. Michelle Moram, Imperial College London

New Light Emitting Diode (LED) technology offers significant promise for reducing the wasteful energy usage associated with lighting and display applications. An ultimate reduction of up to 15% of the total electricity consumption in developed countries could be achieved if LEDs were to replace existing forms of household, commercial and street lighting. This would be achieved not only because of the increased luminous efficacy of LED light sources, but also by increasing the power factor of the entire lighting unit and by introducing control systems that take advantage of the long-lasting, fully dimmable nature of LEDs. However, the high cost of LED-based lighting is the main barrier to widespread consumer uptake today.

This article outlines routes towards improved performance and lower costs, both for LEDs and for the 'luminaire' units they are built into. Because LED lighting can offer additional benefits not offered by current technology, such as their application in indoors wireless data transfer, commercial breakthrough will be driven initially by demand for niche applications. Long-term, however, low-cost LED lighting technology developed with the aid of new materials is likely to play a significant role in the reduction of energy demand both in the developed and the developing world.

The need to reduce unnecessary energy consumption is widely acknowledged in the developed world: as a result, carbon emissions associated with electricity generation and fossil fuel consumption are the subject of increasing regulation. The UK Climate Change Act

2008 has set a legally binding target of a 34% cut in CO₂ emissions by 2020 and an 80% cut by 2050, compared to 1990 levels, while the EU is aiming for a similar reduction of 20% by 2020. Electricity generation is currently the single biggest anthropogenic source of CO₂, so a reduction in electricity consumption will need to be achieved in order to meet these goals.

Worldwide, approximately 20% of electricity is used by lighting and this proportion is predicted to rise by 80 % by 2030

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by 2030, as it is estimated that approximately 1.5 billion people in developing countries do not yet have access to electric lighting. For the purposes of comparison, CO₂ emissions from lighting are approximately three times greater than total emissions from aviation worldwide.

Lighting, Energy and Waste

Globally, a low proportion of our electricity supply comes from 'clean' sources, and this is not expected to change significantly within the next ten years. Consequently, the use of improved light sources could reduce our CO₂ emissions by 5% or more over the next decade alone – a significant amount for just one technological area. Furthermore, lighting is one of the few areas in which a reduction in energy usage can be achieved without impacting performance, so consumers could realistically be expected to purchase and use the new technology. These key advantages make lighting a primary target for reducing energy demand in the developed world.

However, the energy needs of the developing world must also be addressed. Although the per capita use of



energy in developing nations is low compared to that of the developed world, their total energy usage is growing rapidly and has considerable scope for increase far beyond current demands.

The challenge of managing sustainable growth is considerable, and is already the subject of concern for the emerging economies of China and India. Indeed, at the moment, 30 times more energy is used for lighting per person in the USA than in India, indicating the scale of the latent demand in developing countries.

Lighting is one of the few areas in which a reduction in energy usage can be achieved without impacting performance

In this regard, lighting has an important role to play. Reliability and consistency of home, office and street lighting services are an essential enabler of economic growth

and development, and it is not realistic to try to limit their use. However, a reduction in wasted energy by lighting applications can have a significant impact on the development of energy infrastructure. For example, the Chinese government has recently made a very substantial multi-million pound investment into manufacturing facilities for the production of

energy-efficient LEDs, with the aim of reducing energy demand, instead of funding more coal-fired power stations.

Executive Summary

- Energy efficient LED-based lighting could reduce global electricity consumption by around 15% and CO₂ emissions by around 5%.
- Both Defra and the US Department of Energy have identified LEDs as the optimum form of energy-efficient lighting; in the UK: approximately £3 billion in energy costs could be saved each year by replacing existing lighting with LEDs.
- LEDs have higher luminous efficacies than any other lighting technology (up to 200lm/W), but they must be fitted with high-quality electronic drivers and housings to produce high overall energy efficiencies.
- The high initial cost of LED lighting is the main barrier to widespread uptake. An acceptable cost of 1\$/W will be reached by increasing LED efficiencies even further, meaning that bulky, expensive heat sinks can be removed and fewer LEDs can be used to generate the same amount of light.
- To achieve high luminous efficacies and high colour rendering, the existing blue LED and yellow phosphor combination may need to be replaced by phosphor-free multiple-wavelength LED units. The latter will require improved high-power green-emitting GaN-based LEDs (currently a 'missing link' in high power optoelectronics).
- Market breakthrough will only occur when low cost, high-performance LED lamps are achieved. This is likely to occur within the next 5-10 years. In the meantime, consumer trust must be maintained by introducing quality benchmarks and standards to prevent misleading performance claims.

Looking towards the least developed countries, it is also possible to see how advances in energy-efficient lighting technology could assist progress towards meeting the Millennium Development Goals, which include a commitment to the provision of universal education for all children up to primary level, plus a target to improve environmental sustainability and the quality of life for the very poorest. One example involves the use of LED-based energy efficient lighting to enable children in developing countries to complete schoolwork at night. Reliable lighting would be important for a wide range of developing countries, as electricity supplies can be highly intermittent even if a family is nominally connected to their local supply. However, much research still needs to be done in order to increase the efficiencies and reduce the costs of semiconductor LEDs to the point at which they are affordable.

Much research still needs to be done in order to increase the efficiencies and reduce the costs of semiconductor LEDs to the point at which they are affordable

Energy Efficiency

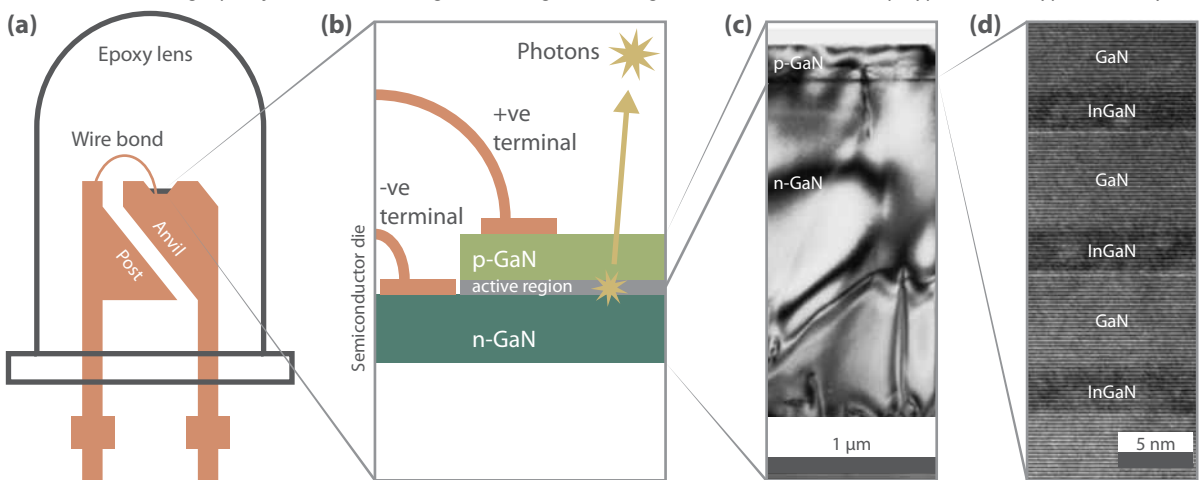
The very first step in developing better LED technology is to understand what efficiency really means. The ability of our eyes to detect light varies substantially, depending on the wavelength of the light. As a result, a simple efficiency measure (e.g. the light output power for a given electrical input power) is of little use. Instead, we need to consider how much of that light will be detected by the human eye: this is called the luminous efficacy of the light source or lighting system. As our retinas are most

sensitive to green light, the best possible light source would emit at this wavelength. However, to produce white light, we need to combine light of at least two different, complementary colours. Consequently, a maximum luminous efficacy can be reached by choosing pairs of wavelengths that remain relatively close, but this comes at a cost: most objects won't reflect light of these wavelengths, leading to poor colour rendering. A compromise must therefore be reached, in which the aim of high efficacy is balanced by the requirement for acceptable colour rendering. Overall,

for a given colour rendering value, we can increase the luminous efficacy by improving any of the components of a typical lighting unit: a light source, a luminaire (or light fixture) which houses the light source with its associated reflectors, electrical circuitry and power connection, and control systems including switches and/or sensors.

The table summarises the main lighting technologies currently in use: their luminous efficacies vary widely. From all of the high-performance lighting technologies, fluorescent lamps already operate close to their maximum efficacy, but LEDs emerge as the most promising lighting technology. The figure shows the construction of a typical LED, on which white lighting is based. Most white LEDs, including the recent record-breaking 200lm/W device, now use the combination of a blue LED and a phosphor, which converts some of the blue light

Structure of a typical GaN-based light-emitting diode: (a) packaged LED; (b) schematic of the light-emitting semiconductor die; (c) cross-sectional transmission electron micrograph of the key regions of an LED; (d) high-resolution cross-sectional transmission electron micrograph of the nanoscale light-emitting InGaN regions, located between 'p-type' and 'n-type' GaN layers.



| Lamp type | Luminous efficacy (lm/W) | Efficacy limits (lm/W) | Initial cost per lumen (\$/lm) | Maximum lifetime (hours) | Warm-up time (min) | Power factor | Dimmable | Frequent switching acceptable |
|------------------------|--------------------------|------------------------|--------------------------------|--------------------------|--------------------|--------------|----------|-------------------------------|
| Oil lamp | 0.1 | 0.1 | N/A | N/A | N/A | N/A | N/A | N/A |
| Incandescent | 8 – 14 | 50 | 0.001 | 2000 | N/A | 1 | Y | Y |
| Halogen | 15 – 25 | 50 | 0.005 | 5,000 | N/A | 1 | Y | Y |
| Metal halide discharge | 60 – 130 | 230 | 0.005 | 20,000 | 2 – 5 | 0.85 - 0.99 | N | N |
| Linear fluorescent | 45 – 100 | 120 | 0.002 | 60,000 | 5 – 20 | ~ 0.4 – 0.7 | N | N |
| Compact fluorescent | 50 – 70 | 120 | 0.006 | 15,000 | 3 – 15 | ~ 0.3 – 0.7 | N | N |
| LED | 50 – 100 | 240 | 0.04 | 100,000 | N/A | up to 1 | Y | Y |
| Organic LED | 18 – 50 | 240 | unknown | 10,000 | N/A | unknown | Y | Y |

Performance comparisons for current lighting technologies

into red, yellow and/or green light. However, the most efficient approach is to combine LEDs of three or four individual colours, avoiding the significant energy losses associated with using phosphors. Research nevertheless still needs to be enhanced, as we do not yet have efficient green-emitting LEDs that work well at high operating powers. Improvements in this area are essential to reduce waste in lighting applications in both the developed and the developing world.

Although efficacy figures are often quoted for a light source alone, in reality a valid comparison can only be made between light sources incorporated into fixtures, which can contain electronic drivers or ‘ballast’ and which may also include light-reflecting and heat-dissipating structures. However, even though some efficiency losses will occur in the driver electronics, their high power factor and efficient direction of light means that a well-designed 10W LED lamp can already provide approximately equivalent lighting to a 100W incandescent bulb, a 30W compact fluorescent lamp, a 20W linear fluorescent lamp or a 20W metal halide discharge lamp. This is particularly important in the developing world, in which the only available source of power may be a battery, capable only of driving low power devices.

In the developed world, significant energy savings can already be made by switching from incandescent lamps to high-voltage linear fluorescent lamps. However, fluorescent lights are not dimmable and usually reach their peak performance only after a warm-up period of several minutes, while their lifetimes are reduced significantly

by frequent switching. In contrast, LEDs can be switched frequently and are easily dimmable, allowing the use of lighting management systems which adapt to external light levels and maintain a minimum level of illumination. By reducing usage, control systems in buildings could cut the energy consumption of LED lighting systems by a further 50%, representing a 95% overall reduction in energy usage compared to incandescent lamps and a 75% reduction compared to linear fluorescent lamps.

A common objection is that increasing the energy efficiency of an appliance could lead to additional wasteful use, particularly in the developed world. However, near-continuous lighting is essential to almost everyone, so there is little room left for careless growth in consumption due to this ‘moral hazard’ on the part of individuals. Consequently, there is little reason to expect the savings due to increased lighting efficiency to be counteracted by an increase in wasteful use. However, other factors are also vital to ensure that the promise of high efficiencies and significant energy savings is realised.

The Economics

Here in the UK, a recent Department for Environment, Food and Rural Affairs (Defra) report highlighted LEDs as the most promising form of energy-efficient lighting technology, as did the USA’s Department of Energy. A very recent US DOE report estimates that over \$20 billion in annual electricity savings would result if high-efficiency LEDs were introduced widely in the US. A closer look at the amount of electricity used for lighting reveals that consumption in the UK is shared between the

commercial (70%), residential (26%) and street lighting (4%) sectors, according to recent Defra estimates. Even though linear fluorescent lamps are already widely used commercially and compact fluorescent lamps are used in about 20% of domestic settings, a comparable figure for the energy savings associated with introducing LED lighting to the UK can still reach approximately £3 billion.

Of course, these savings can only be made if consumers can be persuaded to purchase and use LED lighting. Although regulation can be used to force consumers to do so, such moves tend to be unpopular and politically risky. Economic factors will inevitably dominate consumers' purchasing decisions, and these are influenced strongly by the initial purchase price, which is why cheap incandescent bulbs still comprise around 80% of global sales by volume. Although rising energy costs will tend to promote the uptake of LEDs over less efficient forms of lighting, LED lighting units currently need to be at least 5 times cheaper (ideally 10 times cheaper) than existing alternatives in order to become competitive, as indicated by the \$/lm values given in the table. Obviously, cost minimisation is also of vital importance for the developing world.

To reach the goals of cost minimisation (and hence better energy savings in the real world), we need to focus on the \$/lm figure of merit. It can be increased by improving performance (more lumens of light per \$) or by reducing costs (each lumen of light costs less): fortunately, significant gains in \$/lm values can easily be made through technological improvements. At the moment, the major limiting factor is the efficiency with which electricity can be converted to light within the LED chip, especially at high operating currents. Ultra-high efficiencies of 90% or more will maximise the lumen output for a given chip size and will also reduce waste heat production, resulting in greater reliability, longer lamp lifetimes, reduced fire risks and dramatically reduced heat sink costs. Importantly though, such high LED efficiencies would need to be achieved routinely for large volumes of chips to meet demand from lamp manufacturers. This means that increases in chip efficiencies must also be accompanied by higher yields, achieved primarily through

increased wafer uniformity and high-throughput production techniques (e.g. large-area substrates and thinner, rapidly fabricated LED structures).

To really reduce costs and minimise waste, the lifetimes of lighting units also need to be maximised. The usable lifetimes of the best LEDs can reach 100,000 hours when tested in isolation, and these values are often quoted by manufacturers as the lifetime of the entire lamp assembly. In reality, the latter will be limited by the lifetime of other heat-sensitive components, which can be as little as 5,000 hours. Consequently, clear testing and labelling standards have been brought in within the USA: similar moves should be made as a matter of urgency in Europe.

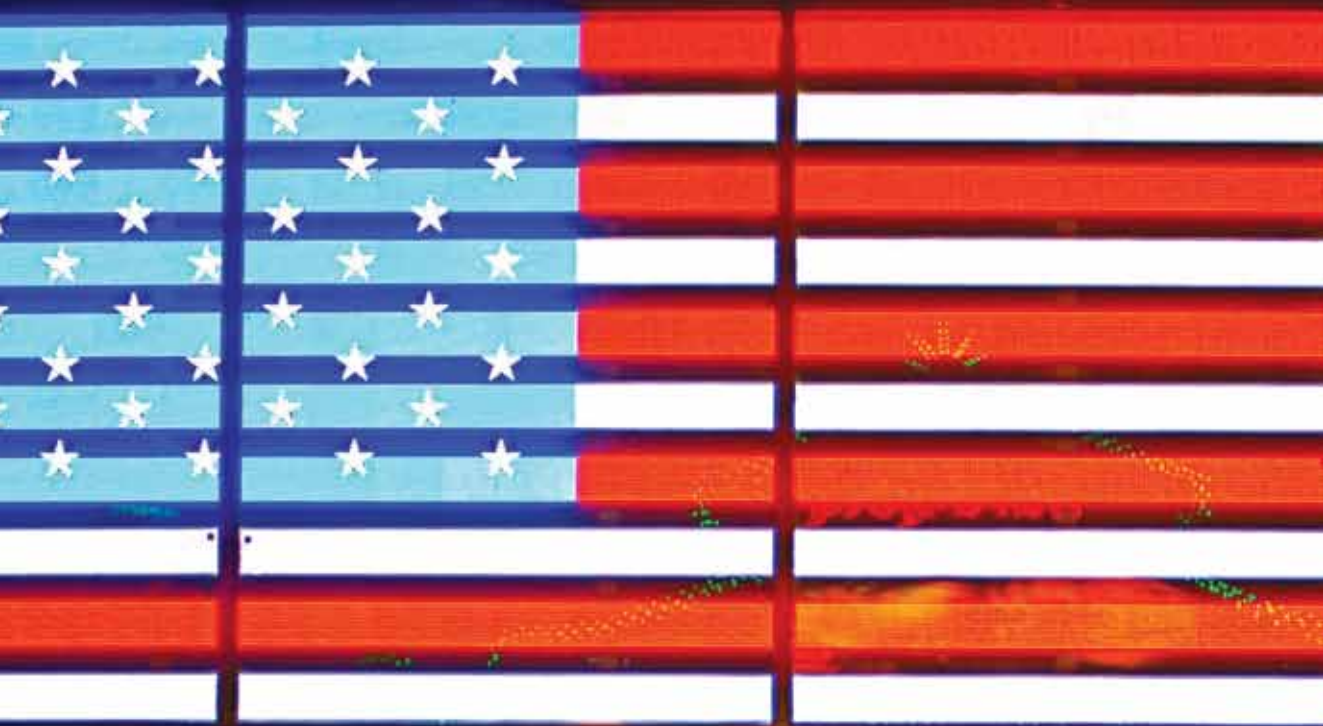
LEDs of the Future

Few competing technologies exist, meaning that conventional LEDs are likely to retain their position as the leading energy-efficient lighting technology well into the future. Indeed, we estimate that world LED production already stands at about 100,000 million (10^{11}) units per year, with projected annual growth rates of at least 10% over the next decade: manufacturing capacity is therefore sufficient to supply the world's needs.

Further benefits are also expected: research aimed towards increasing the efficiencies of LEDs emitting in the visible region should also result in more efficient ultraviolet-emitting LEDs, which could lead to improvements in water treatment applications and hence offer hope to those who currently lack access to clean water.

Such efforts are well worth making – on a global scale, cheap and efficient LED lighting should promote sustainable development, reduce wasteful CO₂ emissions and reduce our dependence on limited fossil fuel reserves.

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Why Our Nuclear Waste Isn't Going Anywhere

Nuclear has had a bad year. Fukushima is a tragic reminder that even modern technology is fallible, and when things go wrong in the nuclear sector, they go very badly wrong. The jury is still out on the long term impact of the Japanese incident, but nevertheless public support for nuclear power around the world is as cautious as ever.

However, with an urgent need to produce vast quantities of clean and secure energy, the UK amongst many other nations is about to embark on a 'nuclear renaissance' with a planned investment of £300 billion in the nuclear sector over the next two decades.

What is to be done about the nuclear waste generated? A technological challenge like no other, it will be 100,000 years before its radioactivity drops to safe levels and, as such, it will need to be stored safely as civilisations rise and fall around it. The answer may lie in deep underground geological disposal, yet this strategy faces strong 'Not In My Back Yard' opposition.

Since Enrico Fermi first achieved criticality in an unshielded pile of uranium and graphite bricks on an abandoned racket court at Chicago University, the nuclear effort has never been incident free. However, despite the catastrophic scale of the largest nuclear incidents, the vast majority of nuclear plants live out their lives quietly and reliably. Based on the International Atomic Energy Authorities (IAEA) 'incident record', there have been a total of 33 significant incidents

in nuclear history, all of which have been classified as less serious than Chernobyl.

Despite safety concerns and the potential for catastrophic accidents, nuclear is still regarded as an excellent proposition as a secure supply of cost competitive and green energy. This portfolio of qualities has not

been overlooked by policy-makers. The world's 435 operational reactors¹ now account for over 15% of global electricity supply², and in the UK our 10 operational nuclear plants power over 16% of all our electricity. The UK anticipates investing £300 billion in the nuclear sector over the next two decades⁴ in the race to reduce emissions

from the power sector to 80% of 1990 levels by 2050⁵. In China this nuclear future is already well underway with 26 plants under construction⁶ – the biggest deployment program in nuclear history.

Furthermore, Uranium fuel is readily available, cheap to extract, and known reserves total over 5 billion tonnes – enough to sustain current consumption for 80 years³. Better yet, the majority of these reserves are found in

A technological challenge like no other, it will be 100,000 years before its radioactivity drops to safe levels and, as such, it will need to be stored safely as civilisations rise and fall around it.

- [1] European Nuclear Society (2011) *Nuclear Power Plants Worldwide*.
- [2] US Energy Information Administration
- [3] World Nuclear Association
- [4] UK Trade and Investment (2010) *UK Nuclear: Powering the Future*.
- [5] HM Government (2011) *Carbon Plan: Delivering Our Low Carbon Future*.
- [6] The Guardian Newsroom
- [7] Union of Concerned Scientists
- [8] Nuclear Decommissioning Authority (2010) *Geological Disposal Steps towards implementation*.

politically stable countries – Australian ore reads much better than Russian gas from an energy security perspective today.

And the waste? Barely a barrel. The nuclear process is so energy rich that a typical 1GW reactor will discharge only 27 tonnes of spent fuel in a full year of operation. At this capacity, a coal-fired plant will release 125,000 tonnes of (significantly radioactive) fly ash⁷ and more than 40 times as much CO₂³. In the UK one palm sized ‘puck’ of waste is all that’s required to supply each citizen with a lifetime’s electricity. Indeed the energy to waste ratio is so high that a recent government inventory⁸ puts all the highly active waste from 50 years of British nuclear power at a mere 12,600m³ – not even enough to fill the stalls of the Royal Albert Hall.

The Fuel Cycle

Releasing nuclear energy is deceptively straightforward. Upon arrival at a power station prefabricated fuel rods need only be loaded into the reactor where, immersed in a sea of neutrons, they spontaneously liberate their nuclear energy, heating water and generating electricity in the conventional way. During this time the fissile uranium isotope U235 is ‘burnt’ and the daughter nuclei build up as ‘ashes’ within the rods. These non-reactive species absorb neutrons and so their rising concentration ‘poisons’ the reactor and the old rods must be removed.

The rods are now extremely radioactive – crammed with unnatural isotopes which must decay to stable forms via the release of dangerously high energy particles. These nuclear processes keep the spent fuel rods as hot as 300°C long after they are removed from the reactor. They must be lowered into water tanks to be cooled, where they will be stored for several years before they can be safely packaged for transport.

Today around 90% of the world’s waste³ remains in such cooling tanks or is packaged and moved to warehouses

for temporary, but indefinite, storage in the shadow of the reactor that produced it. In the UK, cooled waste is sent by rail to the nuclear reprocessing site of Sellafield, Cumbria. Here the 97% un-burnt fuel is chemically isolated from the 3% highly radioactive ashes. The latter are then encapsulated in glass cylinders and sealed in steel barrels. This waste is then provisionally stored on site whilst new fuel rods are manufactured from the recycled Uranium.

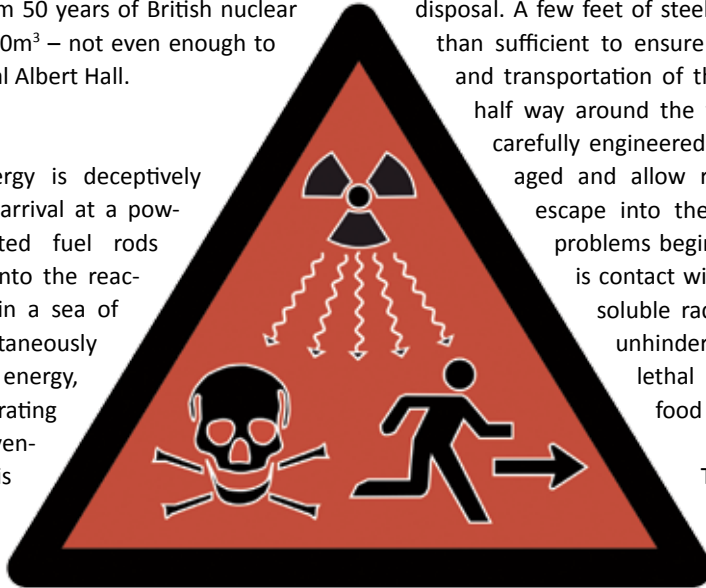
A Solution for Eternity

Despite an extraordinary cool-off period, it isn’t the radioactivity that presents the biggest obstacle to safe disposal. A few feet of steel and concrete are more than sufficient to ensure exposure-free handling and transportation of these wastes, sometimes half way around the world. It is when these carefully engineered canisters become damaged and allow radioactive materials to escape into the environment that the problems begin. Most hazardous of all is contact with water – suddenly the soluble radioactive elements have unhindered opportunity to move lethal doses directly into the food chain.

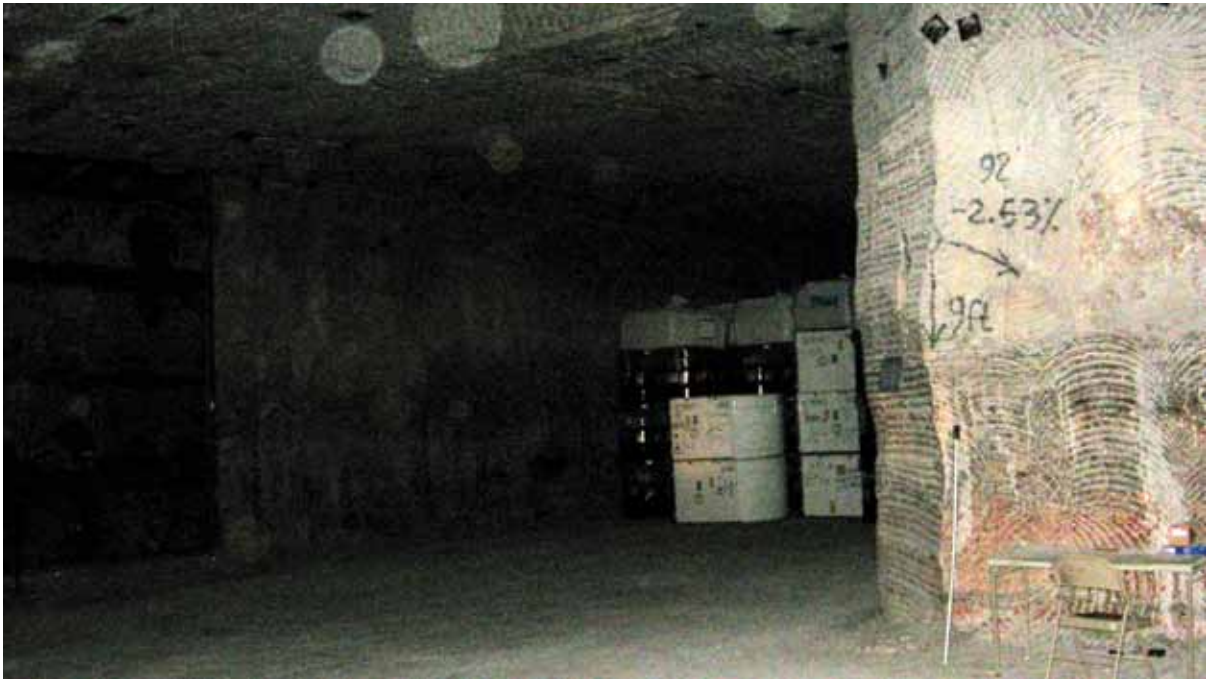
Try as we may to guard against every eventuality, such leaks, although uncommon, are inevitable. Even

under draconian regulation, Sellafield’s THORP reprocessing plant suffered a major internal rupture in 2005, leaking 20 tonnes of reprocessed fuel into its secondary containment vessel. Elsewhere the situation is often significantly worse – the dilapidated Russian naval waste facility at Andreeva Bay has been so heavily contaminated by rusted barrels and cracked storage ponds that it is now isolated under international stewardship for a decommissioning operation that will cost millions⁹.

How can we prevent such leakage now, and in the foreseeable and unforeseeable future? Nuclear scientists must overcome the critical challenge of preventing nuclear waste exposure or leakage for the 100,000 years required for its radioactivity to decay to safe levels.



2007 ISO radioactivity danger logo, designed in part for long-term radioactive waste repositories which might survive into a far future time in which all knowledge of the meaning of present common radiation danger symbols and signs has been lost.



The WIPP project: Waste is stored in rooms excavated beneath 1000m of thick salt formation – the salt bedrock will eventually creep into the repository burying the waste forever

Digging Deep

Since the dawn of nuclear power the waste problem has been tackled with the same perspective – if isolated appropriately, it will be possible to store the waste safely and securely. In 1956 it was the US National Academy of Sciences that first urged the final disposal of high-level nuclear waste in purpose-built underground storage facilities. Trapped outside the biosphere for well in excess of 100,000 years – barely the blink of an eye in geological time – it will remain at a safe distance from human life long after its containers have rusted away.

Since then researchers have been streamlining designs for such underground repositories. Success of these facilities depends critically on location. The repository chamber must be at sufficient depth to be fully insulated from surface processes. Surrounding rock

must be impermeable to ground water flow – minimising corrosion and guarding against water borne dispersal from fractured canisters. Yet it must be porous enough

Today around 90% of the world's waste [is] moved to warehouses for temporary, but indefinite, storage in the shadow of the reactor that produced it

to enable safe dispersal of potentially explosive outgassing of decaying fuel. Last, but not least, the site must be tectonically stable and natural resource free, ensuring neither natural nor industrial intrusion disturbs the waste in its final resting place. A multi-barrier strategy has been devised: 'engineered barriers' are buried within

appropriate host rock ('geological barriers') such that man-made and natural boundaries together ensure the waste is permanently isolated.

The world's first such facility – the Waste Isolation Pilot Plant (WIPP) – accepted its inaugural shipment in March 1999 in Carlsbad, New Mexico. Here, after a planned 30 years of shipments¹¹, the rock salt bedrock will ultimately 'flow' into all of the repository's cracks and crevasses, sealing the nuclear legacy of US defence 650m beneath the desert. The project will cost an estimated \$2 billion¹² over its lifespan.

[9] DEFRA (2008) *Managing Radioactive Waste Safely*.

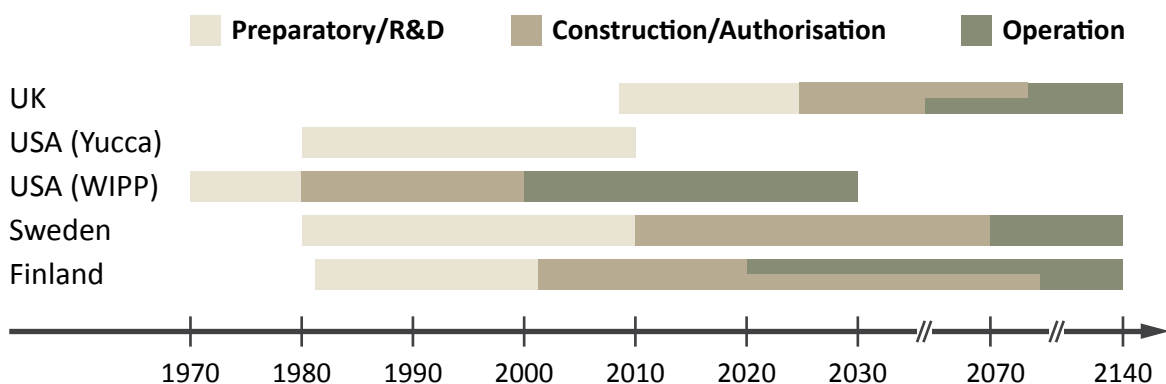
[10] GlobalSecurity.org

[11] New Mexico Department of Homeland Security and Emergency Management

[12] US Department of Energy

[13] Clark D. (2012) New generation of nuclear reactors could consume radioactive waste as fuel. *The Guardian*, 2 February.

[14] British Broadcasting Corporation (2012) Nuclear Waste Consultation Closes [online] Available at: <<http://www.bbc.co.uk/news/science-environment-17476465>> [Accessed 1 April 2012]



Design and operations of first generation geological repositories

Carlsbad repository's sister project for civil waste at Yucca mountain, Nevada, tells a very different story. With no nuclear power plants in the state, and the population already victim of Nevada Test Facility fallout, a two-thirds majority of Nevadans consistently opposed the project which was eventually shelved in 2011 after 30 years and \$9 billion of research and consultation.

Lessons have been learnt. The Posiva facility, under construction on the Finnish island of Olkiluoto, is the world's most advanced repository and currently running to time and on budget. Due to accept its first shipments in 2020, used fuel loaded directly into cast iron holders will be sealed in 5cm thick corrosion resistant copper canisters which will then be stacked inside impermeable cavities in the repository. The lifetime cost of the facility is estimated at £2.5 billion.

In the UK, it is planned that a similar disposal site will be constructed from 2025. Lumbered with 50 years of civil nuclear waste, plans for a prototype repository were put forward in the early nineties, however discussions on its location are ongoing.

Trialled successfully for Posiva, site selection is to proceed on a 'volunteerism' principle by which interested communities may bid to host the facility and its decades worth of investment. Two districts in Cumbria are still in the running – the basis for public support being that most UK radioactive waste is already close by at

Sellafield anyway. The British Geological Survey deems 75% of Cumbrian land sufficiently far from iron and coal reserves that might tempt future generations to start digging, however concerns persist about gas leakage.

As of March 2012 a public consultation is underway to determine if Cumbrians are committed to the next step. Ministers, when asked if there was a Plan B, in case the consultation failed, have repeatedly said that Plan B is to make Plan A work – there is no alternative site¹⁴.

Final Disposal?

With the next generation of nuclear plants expected to produce over 20% of UK electricity by 2030⁵, cohesive plans for long-term nuclear waste storage are more crucial than ever. Furthermore, questions persist at the scientific level: can we efficiently mutate the waste into stable elements? Faced with a 100,000 year legacy, such avenues for fresh research seed political uncertainty – should we ensure repository waste is recoverable in case future generations can or wish to tackle it more effectively?

One thing is for certain – decisions need to be made. It will require decades of consistent policy to ensure that our nuclear waste does not pose a potentially catastrophic risk to generations far into the future. Until then, where is our nuclear waste going? Nowhere further than a warehouse at Sellafield.

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Artificial Photosynthesis: A Carbon-Neutral Future?

Palang Bumroongsakulsawat, Imperial College London

Humans have been heavily relying on fossil fuels, the result of solar energy accumulated through biological processes over millions of years, for centuries. Today we are experiencing an unprecedented increase in atmospheric carbon dioxide, resulting from this fossil fuel consumption, which is expected to result in dramatic climate change. Furthermore, we are simultaneously diminishing traditional fossil fuel stocks, and in search of new cost-competitive and environmentally friendly alternatives.

If only we could convert carbon dioxide into fuel, we could kill these two birds with one stone. Carbon dioxide conversion techniques – processes inspired by nature that mimic photosynthesis – offer a promising solution to these global issues.

For billions of years, there has been an equilibrium between carbon dioxide production by plants through photosynthesis, and carbon dioxide consumption by living organisms via the processes of respiration and fermentation. Essentially, living organisms live on ‘fresh’ solar energy supplied constantly through a natural carbon cycle, while we use mainly ‘fossilized’ energy from the past. This practice, if continued, will irreversibly deplete fossil fuels and hence the race is on to find viable alternatives.

Professor Geoffrey Maitland of Imperial College observes that “it is still expected that 40% of the world energy consumption will come from fossil fuels by

2040. However if even 50% of the carbon dioxide emitted by these fuels could be sucked out from the atmosphere and turned back into high-energy organic molecules, carbon dioxide levels would essentially stay where they are now.”

While significant progress has already been made in the development of new ‘green’ energy sources such as solar and wind, we still lack a process similar to that plants use to convert carbon dioxide into carbohydrates. Technologies for simple carbon dioxide conversion into fuel-products, however, are already available at industrial scale.

While significant progress has already been made in the development of new ‘green’ energy sources such as solar and wind, we still lack a process similar to that plants use to convert carbon dioxide into carbohydrates

An example is methanol synthesis from carbon dioxide and hydrogen employing an appropriate catalyst. In this case, the energy for converting carbon

dioxide is supplied by hydrogen and therefore the source of hydrogen, decides whether or not the process contributes to carbon dioxide emissions.

Alternatively, carbon dioxide can be converted directly through electrochemical processes. When a large enough voltage is applied to an aqueous solution containing carbon dioxide, the carbon dioxide is converted

- [1] US Department of Commerce/Earth System Research Laboratory (2012) Trends in Carbon Dioxide [online] Available at < <http://www.esrl.noaa.gov/gmd/ccgg/trends> > [Accessed 4 April 2012]
- [2] Hui, L. & Oloman, C. (2006) Development of a continuous reactor for the electro-reduction of carbon dioxide to formate – Part 1: Process variables. *Journal of Applied Electrochemistry*. **36**(10): 1105-1115.

into various potential fuels or fuel generators such as formate, carbon monoxide and methane.

More recently a new technique inspired by the delicate chemistry taking place in plants has been proposed. An 'artificial leaf' converts solar energy into hydrogen, which in turn can convert carbon dioxide into fuel. If this process is successful, and can be implemented at scale and cost, it could resolve some of the issues surrounding intermittent solar electricity generation from 'conventional' solar cells and most other renewables, and form a crucial component of a carbon-neutral fuel cycle.

Sourcing Carbon

For traditional carbon conversion technologies, carbon capture and storage is a major component of the process. Although carbon dioxide is present in the atmosphere, even at a higher concentration than in the past few centuries, its presence is still in ppm (393.65 ppm¹ in February 2012 at Mauna Loa, Hawaii). Direct extraction of carbon dioxide from the atmosphere is expensive, and ideally we should capture it at source.

Installing a compressor and a carbon dioxide tank directly at an exhaust pipe of a combustion engine would give rise to a mixture of carbon dioxide, water and oxygen – impractical for most conversion techniques. In a fuel cell, however, carbon dioxide and water form in different compartments and therefore pure carbon dioxide can be captured.

Converting Carbon

Technologies for carbon dioxide conversion include methanol synthesis from carbon dioxide with the energy for the conversion supplied by hydrogen, which in turn must be derived from some energy source. For example, water can be split into hydrogen and oxygen when a large enough voltage is applied. So, if this electricity is supplied from renewable sources, the methanol synthesis process can produce fuel from carbon dioxide in an emission-free manner.

How efficient is this thermochemical process? The efficiency of an electrochemical cell for hydrogen production is about 50%, which is appropriately reduced by the efficiency of the electricity supply – ending up with say

10% efficiency for solar power input. However, only 85% of the energy from the carbon dioxide conversion reaction can be stored in methanol, leaving an estimate of the maximum efficiency of the entire process at around 8%.

Why can't we use hydrogen directly as a fuel? Hydrogen is an attractive fuel because it has very high specific energy, its only combustion product is water and it can be used in modified combustion engines without replacement fuel cells. However, it has a low energy density in uncompressed states, and the compression process is often risky and expensive.

Alternatively, carbon dioxide can be converted directly into fuel-products through electrochemical processes. Perhaps the easiest way is to do this in an aqueous solution containing carbon dioxide. When a large enough voltage is applied, carbon dioxide is converted into various products such as formate, carbon monoxide and

methane. The first two chemicals are not common as fuels because they produce little energy when burnt, but could serve as reactants for other processes to produce better fuels.

If artificial photosynthesis systems could take up around 10% of the sunlight falling on them, we would only need to cover 0.16% of the Earth's surface to achieve a global energy consumption rate of 20TW – the predicted amount of energy the world will need in 2030

methane. The first two chemicals are not common as fuels because they produce little energy when burnt, but could serve as reactants for other processes to produce better fuels.

For the electrochemical conversion of carbon dioxide, the required total voltage roughly triples that needed thermodynamically². In other words, 33% is typical efficiency from the electrochemical cell. Again, a solar panel with 20% efficiency would diminish the maximum efficiency of this process to 6%.

These numbers are merely illustrative of the difficulty in converting renewable energy into fuels. The losses presented here do not represent the whole process and the numbers are likely to be smaller, and/or change comparatively, when efficiencies of auxiliary units of both processes are taken into account.

The 21st Century Leaf

Just like living leaves, the 'artificial leaf' is a cyclic system where the two basic steps of photosynthesis take place. The first one, consisting of the splitting of water



into hydrogen and oxygen in the presence of sunlight, is a water electrolysis reaction at the cellular scale. The 'clean' hydrogen produced can then be directly used as fuel, or employed in carbon dioxide conversion schemes such as those outlined above.

The world's first practical 'artificial leaf' was invented by MIT researchers last year: it is a solar cell composed of a thin sheet of semiconducting silicon coated with different catalysts on each side. It is placed into a water container and exposed to sunlight to generate bubbles of hydrogen on one side, and oxygen on the other.

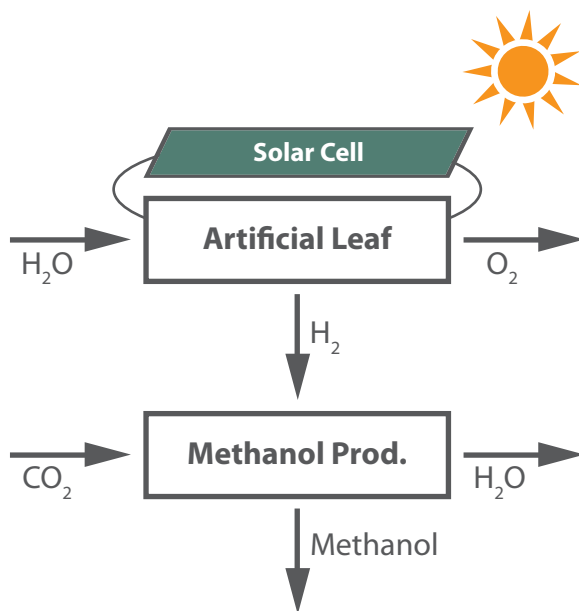
Research in the photovoltaics area is growing rapidly, but producing cost-effective technology that can compete on price with fossil fuels is the major challenge. Unlike the other two main energy production systems powered by the sun - photovoltaics and solar thermal devices - hydrogen-producing artificial leaves could be produced cheaply. The device is composed entirely of inexpensive, abundant materials - mainly silicon, cobalt and nickel - and operates under simple conditions, that is, in ordinary water³.

The leaf created by the MIT researchers can currently convert 2.5% of solar energy falling on it into hydrogen in its wireless form. When using electrical wires to connect the catalysts to the cell instead of linking them together, the efficiency increases to 4.7%⁴.

If the leaf can do it, we can do it even better

Hence, electricity generation from the water splitting reaction is promising, but it is not realistic that batteries alone could power cars or aircrafts. The next question is whether we can take a step further and develop cheap, reliable and efficient catalysts to make high-energy chemical bonds using sunlight.

Imperial College's Artificial Leaf Project, spearheaded by the Energy Futures Lab, is working on the solar driven reduction of carbon dioxide to energy rich carbon based fuels. Approaches range from direct photochemical reduction of carbon dioxide and photovoltaics plus electrochemical carbon dioxide reduction to solar water



Solar energy is used to produce hydrogen from water – potentially via artificial leaf technology – which in turn is used to convert carbon dioxide to methanol fuel

photolysis coupled to the dark reduction of carbon dioxide by molecular hydrogen.

A Carbon-Neutral Future

Professor James Barber, leader of the Artificial Leaf Project, is optimistic. He argues that if artificial photosynthesis systems could take up around 10% of the sunlight falling on them, we would only need to cover 0.16% of the Earth's surface to achieve a global energy consumption rate of 20TW – the predicted amount of energy the world will need in 2030⁵.

He follows on that "incredible amounts of activity are already being put into the field of artificial photosynthesis ... (but) it is very hard to predict how fast this new, cutting-edge technology encompassing solar research will be mastered into a workable system."

"If the leaf can do it, we can do it even better"

Prof James Barber, Imperial College 2012

[3] American Chemical Society (2011) 27 March, Debut of the first practical "artificial leaf" [Press release]

[4] MIT News (2011) 'Artificial leaf' makes fuel from sunlight [online] Available at: <<http://web.mit.edu/newsoffice/2011/artificial-leaf-0930.html>> [Accessed 30 March 2012]

[5] Jha, A. (2009) Scientists explore how the humble leaf could power the planet. *The Guardian*, 11 August.

Palang Bumroongsakulsawat is a PhD student working on electrochemical conversion of carbon dioxide. He focuses on kinetics of carbon dioxide, and using semiconductors as electrodes to capture photons for the conversion of carbon dioxide in a single device.

Arsenic: Mass Poisoning in the 21st Century

Florence Bullough & Chris Moffat, Imperial College London

Access to clean water is a fundamental human need, and has been described by the United Nations as a human right 'essential to the enjoyment of life and all other human rights'. Yet the presence of contaminants in drinking water, whether biological or chemical, is widespread, causing disease and death around the globe.

The challenge is thus to find both low-cost reliable ways of analysing toxic contaminants in the field, and develop cheap and effective remediation methods. These will be particularly beneficial to developing countries with limited resources for detection of arsenic, the most toxic of them all, in water.

Arsenic-contaminated drinking water has been identified in many countries around the world including Argentina, Australia, India, Mexico, Thailand and Bangladesh. The World Health Organisation (WHO) declared the problem in Bangladesh to be 'the largest poisoning of a population in history', with up to 104 million people affected.

Arsenic in drinking water is dangerous even at very low concentrations through cumulative exposure over a number of years. Concentrations as low as 10 micrograms per litre (or parts per billion – ppb) can be toxic in humans, causing cancer and other serious illnesses. A recent reduction in the guidelines for maximum arsenic concentration from 50 to 10 ppb by the WHO in 2006, also adopted by the US Environmental Protection Agency, has increased pressure to develop detection and remediation technology.

Reliable determination of arsenic concentrations in the lower ppb range (0-20 ppb) is difficult and is usually carried out using sophisticated and expensive lab-based techniques. Such analysis is too costly for many countries, and hence they have not been able to implement the new rules. The challenge now is to find both low-cost and reliable ways of analysing arsenic in the field in addition to finding cheap and effective remediation methods.

Chronic Exposure

The toxic nature of arsenic is notorious, with its use as a poison throughout human history well documented. However, long-term exposure to arsenic from environmental sources (chronic exposure) causes symptoms that are very different to those resulting from acute poisoning, and can result in a range of very serious health problems.

Concentrations as low as 10 ppb are responsible for causing a variety of cancers, cardiovascular and lung diseases, gastrointestinal illness and neurological disorders. Dermatological effects are also very common, with more than 1,000 people known to have developed skin disorders caused by intake of arsenic released during mining in the Ron Phibun region of Thailand alone. Such derma-

tological effects, due to their visibility, are often used as an indicator that chronic exposure is occurring in a given environment. Long-term exposure to arsenic has also been implicated in the impairment of children's neurological development.

Arsenic occurs naturally in two forms, namely arsenite and arsenate. Arsenate usually exists as a negative ion (except in very acidic waters) which is chemically very

The World Health Organisation declared the problem in Bangladesh to be 'the largest poisoning of a population in history'

similar to phosphate (ubiquitous in biology). This means that arsenate can replace phosphate in biological systems, thereby interrupting the delicate biochemistry of living cells. One such case where this can occur is ATP (adenosine triphosphate), which has an extremely important role in the storage and transfer of energy within cells. Arsenite is capable of interrupting important biochemical pathways in a different way, by binding to enzymes and disrupting their function.

The carcinogenic properties of arsenic arise from its propensity to damage DNA. The risk of developing cancer from exposure to drinking water containing 50 ppb arsenic is 100 times greater than the risk posed by any other contaminant at this level.

In 2006 the WHO reduced their guidelines for safe arsenic levels from 50 to 10 ppb. Without swift action, it can be expected that future disease rates of those exposed will rise as long-term exposure to these dangerous levels continues.

Adsorbing Arsenic

Naturally occurring arsenic is generally found either adsorbed to the surface of clays and minerals, or is actually incorporated within the mineral structure. It can be mobilised into groundwater through the dissolution of the supporting mineral or through desorption from the surface.

The risk of developing cancer from exposure to drinking water containing 50 ppb arsenic is 100 times greater than the risk posed by any other contaminant at this level

The two naturally occurring forms of arsenic – arsenate and arsenite – possess quite different physical properties. The type of the water source in question determines which form is found: in oxygen-rich waters arsenate (+5 oxidation state – As^v) prevails, and in oxygen-poor waters arsenite (+3 oxidation state – Asⁱⁱⁱ) dominates. In most natural waters,

the negatively charged arsenate can stick to positively charged surfaces such as iron oxide minerals (adsorption), whilst neutral arsenite is much less readily adsorbed by surfaces.

Thus, the general idea of remediation technology is that materials such as iron oxide are used as adsorbents to remove arsenic from the water. For example, the large purification tanks at the Severn Trent Water arsenic adsorption plant, Worcestershire, contain an iron oxide

Bangladesh: The Largest Poisoning of a Population in History

WHO estimate that up to 104 million people in Bangladesh have been affected by arsenic poisoning. Although the problem only came to light relatively recently (in the late 1990's), arsenic contamination in Bangladeshi groundwater goes back to the 1970's, when UNICEF began to drill deep tube wells.

The wells were intended to provide new clean water sources, and alleviate widespread health problems such as cholera and dysentery that resulted from drinking polluted surface waters. However, the drilling of these wells reached rock layers that contained naturally occurring arsenic minerals – this arsenic was then mobilised and entered the drinking water supply. The tube wells were drilled all across the country and became the main source of water for drinking, bathing, washing, irrigation and cooking - meaning that the exposure to arsenic was, and continues to be, multi-source.

Despite knowledge of the problem today, many households, particularly in the Bengal delta, cannot decontaminate their water due to the high cost, and poor access to, removal technologies. In addition to contamination issues, social issues also arise from the stigmas attached to the development of symptoms and owning a contaminated well.

These problems, coupled with a lack of access and understanding of remediation technology, have created a serious and complex contamination crisis. The development of new cost-effective materials and technologies that can be used to make currently toxic waters safe is therefore a major goal for many scientists.

material. As contaminated water is passed through the adsorbent, the arsenate sticks to the surface and is removed from the water. However this method remains more effective for removing arsenate than arsenite. Pre-treatment of water, either to convert arsenite to arsenate or to lower the pH (which both improve uptake of arsenic) is common.

Iron oxides have also been exploited in much cruder filters, designed for use in the developing world and particularly rural areas, where the remediation techniques (including point-of-use, community and aquifer wide removal plants) are much more rudimentary. Examples of these include household systems such as the SONO filter, developed in 2001, which consists of stacked plastic buckets filled with an iron matrix, coarse sand, charcoal, brick chips, and fine sand. Up to 20 litres of water can be filtered per hour using this filter whose lifetime can sometimes reach five years. Community removal plants, on the other hand, consist of up to 3 filters directly fitted to pump wells.

However the effectiveness of both SONO filters and community devices remains unclear. A study completed in 2005 highlighted the failure of community removal plants in West Bengal to remediate arsenic levels below 50 ppb. Tests carried out for the SONO filter were more promising, as results showed an arsenic concentration in the filtered water of less than 10ppb-limit set by the WHO.

On a larger scale, subterranean arsenic removal technology (SAR) involves the pumping of aerated water back into the aquifer causing oxidation of arsenite to arsenate (as the oxygen content of the water is increased). This approach has the advantage of addressing the arsenic

present in both domestic and irrigation water. However, if the planned oxidation is poorly calculated, arsenic may precipitate, leading to longer stabilisation periods in the initial stages.

Many current remediation technologies also face problems due to the presence of other chemical species in groundwater interfering with the arsenic uptake process. For example, phosphate, chemically similar to arsenate, is often found at much higher concentrations. Phosphate ions compete with arsenate at the adsorbent surface, and either cause the arsenate to desorb from the surface, or block adsorption sites, thus inhibiting arsenic removal.

The general idea of remediation technology is that materials such as iron oxide are used as adsorbents to remove arsenic from the water

Phosphate competition presents a real challenge which could be overcome either by designing new materials with a more specific arsenate binding ability or via

(potentially expensive) water pre-treatment processes. However, the more complex and involved the processing and treatment stages, the less likely developing countries will be able to afford to implement the technology.

Toxic Waste

Dealing with the waste produced post-remediation raises further issues in developing countries. The disposal of arsenic remediation waste is difficult because leaching or loss of arsenic from waste can result in further contamination. Adsorbent technology often results in the formation of arsenic-containing liquid-waste that requires a high standard of waste management for proper and safe disposal. Therefore adsorbents resulting in a solid waste, that is suitable for landfill, are preferable.

Solid wastes can then be tested for their stability and leachability in various settings, and be separated into hazardous and non-hazardous substances. Wherever specific facilities are not available, this waste may be dealt with informally by spreading it on land, diluting and dispersing it into rivers or casual landfills.

A novel method was recently proposed suggesting that arsenic remediation sludge should be mixed with cowdung so as to form methylate arsenic which then no longer poses a risk. This is similar to the use of sludge in brick making; mixing it with clay immobilises the arsenic. Designing efficient, long lasting materials that do not

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In a flooded paddy, a boy from Bashaibhog village, Bangladesh helps to collect porewater samples from various sediment depths where arsenic contamination levels are typically around 400 ppb and can be up to 2500 ppb

require frequent regeneration (hence minimising the total volume of waste needed to be disposed of), is the best way to effectively tackle the issue of waste resulting from arsenic removal.

Clean Water for All

Research into all aspects of the arsenic problem, from detection of low concentrations to developing new remediation materials, is currently on-going at Imperial College. The aim of this research approach is to design a two-stage model in which both forms of arsenic are removed from drinking water at once.

The first stage utilises a novel titanium dioxide/iron oxide material, together with UV irradiation, to oxidise the more toxic arsenite to arsenate. This first stage serves to eliminate important competing ions such as phosphorus in order to make stage two more efficient. The second stage of remediation then focuses on binding the residual arsenate, thus bringing arsenic levels below recommended levels.

Adsorbent technology often results in the formation of arsenic-containing liquid-waste that requires a high standard of waste management for proper and safe disposal

It is clear that arsenic contamination poses a number of important challenges to governments, regulatory agencies and researchers around the globe. Low-cost detection of low levels of arsenic is a key priority, and, while remediation technologies have been implemented with some success, the implementation of efficient and affordable arsenic filters in the developing world is urgently needed. Only with a combined effort from scientists, engineers, aid agencies and governments can this global problem be truly confronted.

The goal of providing clean water for all of the world's population presents an inspiring challenge, both in human and scientific terms, and is the driving force for much innovative and exciting research around the world.

This project is being completed under the supervision of Dr. Dominik Weiss in the Department of Earth Science and Engineering and Professor Ramon Vilar in the Department of Chemistry.

Florence Bullough & Chris Moffat are PhD students in the Department of Earth Science and Engineering at Imperial College London.

Healthcare in the Sahrawi Refugee Camps

Alavari Jeevathol, Imperial College London

In 1976 the Sahrawi people, fleeing Moroccan occupation of their neighbouring home nation of Western Sahara, were forced to settle in refugee camps in Tindouf, Algeria. Now, more than 35 years since the first settlements were formed, these temporary camps have evolved into a functioning society. However, the harsh desert environment has forced the camps to rely almost exclusively on international humanitarian assistance for their survival.

The Sahrawi people have had to build a health care system for themselves out of the bare, dry, desert. How did they do it? And what are the major challenges they continue to face?

The Sahrawi people are one of the longest-standing refugee populations in the world. The Sahrawi Arab Democratic Republic (RASD) was formed in 1976 by the Sahrawi people in exile. The political situation has been tense to say the least, with the positions of both Morocco and the Polisario Front, the national Sahrawi liberation movement, having been endorsed by the Arab League and African Union respectively. Loosely summarized, the Spanish and Algerians have long supported the Sahrawis, with France and the US shoring up the Moroccan side. Despite a clear ethical imperative to resolve the Sahrawi situation, gathering the political will to further their cause at the UN has been difficult.

The 165,000 Sahrawi refugees living in neighbouring Algeria are resolute about the temporary nature of the camps, despite a serious lack of water, shelter and medicinal resources, for which they currently depend

almost entirely on foreign aid. Yet, RASD has a level of organisational structure that most refugee populations, such as those in Sudan, Chad or even in Palestine until the last few decades, have not attained. For the Sahrawis, the settlements are only models, prototypes to help them qualify for the 'official right' to self-rule in the eyes of the international community, and to assist in the transition and initial periods of that rule.

The combined World Food Program (WFP), Human Aid and Civil Protection department of the European Commission (ECHO) and United Nations High Commissioner for Refugees (UNHCR) multilateral aid to RASD was \$30 million in 2007. To put this in perspective, as Western Sahara Resource Watch point out, Morocco

would have earned in the region of \$15 billion on phosphate resources taken from the territory they occupy in Western Sahara during a similar period. For the Sahrawis, it is a desperately unhealthy, poor and uncertain existence in the camps – they live with the fear that international assistance could dry up at any time.

A Home in the Desert

The Sahrawi refugees are spread mostly between four main settlement districts or *wilayas* – 'Laayoune', 'Awererd', 'Dakhla' and 'Smara', located on the *hammada* (the flat, dune-less desert plain region of the Sahara). 'Rabouni', '27 February' and '12 October' are all fast growing satellite camps nearby. The camps comprise of thousands of flimsy clay, sand and brick dwellings

The Sahrawi people have literally had to build a health care system for themselves out of the bare, dry, desert

strengthened with scrap metal and stones which offer inadequate shade from the intense 50°C heat. For the most part, the huts have traditional nomadic tents (which stay cooler during the day) erected close by. The *wilayas* otherwise comprise of slightly larger brick structures for schools and municipal meeting places in between rocky outcrops and water tanks on which small children play.

The soil is arid and infertile. Food and other basic amenities are available from the typically Arab-style marketplaces, mainly scrounged from the limited trade links with Mauritania to the south. Chronic malnutrition was recently recorded to be 19% for the child population, exceeding the UN estimates of 15% child malnutrition constituting an ‘emergency crisis’. Camp-wide estimates show roughly 33% malnutrition. World Health Organisation (WHO) reports of endemic childhood anaemia are worryingly persistent: 35% in 2002, 69% in 2005 and 61% in 2008.

The Beginnings of a Health System

Initially starting out with only five nurses and two medical students, Mr. Sidahmed, RASD Minister of Health, (himself initially one of those two medical students) now has a system comprising of regional hospitals each capable of handling several dozens of patients at a time in every *wilaya*, with local clinics in each *daira* (sub-district) to penetrate as deep into the maze of huts as possible.

Mr. Sidahmed identifies prevention as the best strategy for their disadvantaged health system. Several Sahrawi doctors admit, however, that with many illnesses, they still have to contend with traditional healing practices, which empirically seem to be counterproductive. As an old lady practitioner in Smara, skilled in herbal medicines, softly proclaims: Allah is the ultimate decider of fates.

Medical supplies typically fill one ceiling-high cupboard and mini-fridge per hospital, and equipment is fairly outdated. Lighting and power are frequently cut off, especially in Smara and Dakhla, with obvious repercussions for what limited, overburdened x-ray and laboratory capabilities presently exist. Beyond chronic diabetes-related conditions, skin lesions and acute malnutrition/

anaemia, serious cases are referred up the chain of command to the camp hospitals, and beyond that to the national hospital at Rabouni, and finally to Tindouf in Algeria proper. Here the critically ill (mainly complicated pregnancy cases) are received – that is, if they have survived the road journey – by the Algerians.

Ibrahim, a nurse working in the accident and emergency room at the national hospital in Rabouni (which is quite literally just a medium-sized room with half a dozen beds), has to carefully ration such items as saline or glucose drips, bandages and needles, improvising his clinical procedures with whatever comes to hand. He has no time or means to pursue differential diagnoses like UK clinical codes of practice dictate, neither do the doctors, surgeons or GPs. Gut feeling guides many of the doctors’ snap decisions on patients, in what is either extremely good experience at dealing with repetitive case presentations, or necessary restriction of patient processing to just the most basic physical examination and history taking. It could be seen as dismissively quick or conversely, just efficient and utilitarian.

Only a handful of doctors specialising in obstetrics and gynaecology (always prioritised over the other medical specialties in any Sahrawi hospital), general surgery, ophthalmology, and paediatrics are spread around the six or so hospitals in the camps. There is little redundancy in the system and it can easily get overwhelmed or diverted, mostly at Rabouni, where ‘referral bottlenecks’ can form.

The problem, as the main urologist at Rabouni explains, is that Sahrawi doctors (himself included) are trained in Cuba and Spain, countries with whom the Sahrawis share a language and have past colonial ties. But he says there is little incentive to come back – as poorly as it may reflect on the young Sahrawis – because a camp doctor’s life is very tough. He is on call 24/7, with long periods of inactivity sporadically punctuated by intense work periods. For the past several years, he has had no private life and little time to spend with his family, and is often rushing between *wilayas* at 2 or 3am.

However, emigration may indeed prove useful for raising awareness of the Sahrawis’ plight through networking

Chronic malnutrition was recently recorded to be 19% for the child population, exceeding the UN estimates of 15% child malnutrition constituting an ‘emergency crisis’



and deployment of aid missions. Several such missions have built air-conditioned laboratories in the national hospitals over the years and performed mass ophthalmological and general check-ups in the camps. This has in itself reduced the workload on doctors. It is difficult to know what the future holds for this new generation born unfortunately into refugee status, yet still with ambitions and dreams of their own.

Rationing Care

For some twenty years following the occupation, there was an armed struggle that left many thousands dead and many hundreds wounded. Mr. Hanshi is director of a landmine hospital near one of the settlements, founded by a St. John Ambulance mission to Algeria. There are around 60 patients, wheelchair-bound, paraplegic or quadriplegic in his charge. Aged patients are the

majority and are housed in small, bare rooms. Some of them have their families for company, while others have just the handful of staff employed to assist them.

Medical supplies typically fill one ceiling-high cupboard and mini-fridge per hospital, and equipment is fairly out-dated

At the main pharmacy (also a sorting house for medical aid) in an outpost between the camps, the administrator has the task of allocating ECHO and UNHCR supplies for division and delivery to the various hospitals and clinics. Then the question arises of how much should one set aside for palliative care when assessed against the general medical needs of the population. A tough choice to have to make, assuming the supplies actually do arrive on schedule, which, as the administrator freely admits, they often fail to do.

UNHCR workers located at Weather Haven compound in Rabouni say that estimating the total refugee numbers, let alone their health status, has been extremely difficult for a wide variety of logistical, cultural, political and bureaucratic reasons. They are wary of overstepping

The Sahrawi refugees are resolute about the temporary nature of the camps, despite a serious lack of water, food and medicine





The emerging Sahrawi health system is thought of as a prototype for a future functioning and recognised Sahrawi state

their authority with RASD authorities in what is certainly unfamiliar territory for them. How far WHO, Mundubat, UNHCR, ECHO and the WFP should implicate themselves in the running of the camps is a key question. Offending or intruding upon the Sahrawi stance of refusing to see these settlements as permanent arrangements (despite 36 years of frustrating exile), is something they want to avoid.

Political Solution or Continued Aid?

The background to all of this is of course the terrible food and water shortages affecting particularly Sahrawi children, for whom time and delayed action means a consignment to morbidity. In the short term, improving things in the camps must be the priority. Food and medicine delivery need to be regulated, normalised and preferably increased as the Sahrawi population expands and water resources dwindle. Activism fostering strong public awareness and discussion of these issues is paramount to ensure Western governments maintain this aid, yet continued aid is not the ultimate solution.

The role of the Algerian and Spanish governments has so far been a mixed one. On the one hand they have given invaluable aid and some diplomatic assistance, but to what extent should they adopt a more proactive

policy concerning the plight of the Sahrawis, and offer a convincing opposition to France and Morocco, the main antagonists of Sahrawi self-determination in the UN?

Political activism via social media such as that carried out by Resistencia Sahraui, and independent news organisa-

tions such as The Real News and Democracy Now are helping to increase pressure on Moroccan and French authorities to sit

down with RASD leaders and appreciate their moral imperative to facilitate democratic steps forward.

The Sahrawis will continue to lobby, protest, and persist against the odds. Meanwhile we have to decide whether to pass the buck or accept our ethical responsibility to lobby on their behalf.

How far should WHO, Mundubat, UNHCR, ECHO and the WFP try to implicate themselves in the running of the camps is a key question

Alavari Jeevathol is a final year undergraduate in Biomedical Sciences specialising in Neuroscience & Mental Health at Imperial College London. He visited the Sahrawi refugee camps in Algeria last year with the charity Global Action for Development (GLAD).

Detecting Cholangiocarcinoma

John Chetwood, Imperial College London

Cholangiocarcinoma is a malignancy arising from the bile ducts, both inside and outside the liver. Despite its relative anonymity outside specialist medical circles, we have good reason to be concerned – it is showing worrying increases in incidence across all continents and is one of few cancers where technological advance has offered little improvement in prognosis over the last few decades. Widespread in South-East Asia due to parasitic infection, it is now also the most common cause of primary liver cancer mortality in the UK largely due to the fact current treatment options are so ineffective.

New award-winning work at Imperial College, however, shows promise for the development of simple, low-cost urinary markers that could revolutionise early detection of this disease and thus significantly improve survival prospects for patients.

Cholangiocarcinoma of the liver is on the rise, with worrying increases in incidence across all continents, and a 15-fold increase in the UK alone since 1968. Currently the only hope of a cure is early detection followed by surgical removal. However, the disease normally presents too late for this to be possible and mortality rates are extremely high, which means that incidence almost equals mortality; i.e. nearly everyone who contracts this cancer will be killed by it (in very few other cancers is this true). This bleak situation becomes worse when one considers the extremely large disease burden in South-East Asia. Mainly due to parasitic infestation, this cancer is overwhelmingly common in areas like Khon Kaen in rural Thailand.

In Khon Kaen, incidence rates have reached over 300 per 100,000 and it is not an uncommon sight to see an entire ward of young men and women jaundiced and cachectic, close to death. Quite apart from the staggering disease burden, it also presents a large development hurdle, often tearing families apart and leaving single parents to care for large families or even orphaning entire groups of siblings.

South-East Asian hill tribes and rural communities are often impoverished, isolated, and have significant cultural barriers that might limit the social acceptability of invasive testing. Although there is infrastructure in place to treat the disease (albeit often basic), these centres are often too far for communities to bother with routine screening or even to arrange consultations for non-severe symptoms.

Thus, there is an urgent need to find an accurate, cost-effective, transportable, non-perishable, and culturally

permissible way to screen for this cancer in these communities, and worldwide.

The Idea

Our hope was that we would be able to achieve this through urine analysis, particularly a simple urine dipstick – the kind of test that is currently used to detect blood, sugar and infections in urine as well as diagnose pregnancy. It could also be used to follow up patients and detect recurrences after treatment.

The reason cholangiocarcinoma research efforts have previously had such little effect on survival is due to the

The development of simple, low-cost urinary markers ... could revolutionise early detection of this disease

cancer's unique characteristics (see box next page). We hope that the emerging field of metabolomics could hold the key to a new method of cholangiocarcinoma detection.

Metabolomics is the comprehensive quantitative analysis of metabolites in a biological system¹. This work is increasingly popular at Imperial College especially in gastroenterological and hepatological fields where other investigative modalities may lack accuracy or be extremely invasive. This seemed to be a good starting point given this modality's success in isolating detectable markers in other cancers, including a urinary marker for another liver cancer (hepatocellular carcinoma), and the fact that previous work had identified metabolite changes inside people with cholangiocarcinoma.

In Khon Kaen, incidence rates have reached over 300 per 100,000 and it is not an uncommon sight to see an entire ward of young men and women jaundiced and cachectic, close to death

Given Imperial College's other success with urinary metabolomics, a developed dipstick for cholangiocarcinoma could also potentially incorporate markers for other diseases such as hepatitis C and hepatocellular carcinoma – to give a much more thorough screening of isolated communities.

Furthermore such work has the opportunity to illuminate the way such a poorly understood cancer arises, which may have preventative and treatment-target ramifications.

The Patients and Profiles

Blood and urine samples were collected from cancer patients (later histologically proven) and healthy controls in Khon Kaen, Thailand. These samples were brought back to MRC Harwell, Oxfordshire for analysis in an 11.7 NMRS machine. As a pilot study with significant

Opisthorchis Viverrini (top two) and Clonorchis Sinensis (bottom), both parasitic worms infecting the human bile ducts, predispose the hosts for Cholangiocarcinoma



Cholangiocarcinoma

- The cancer is inherently extremely aggressive
- Parasite eradication is not possible with current resources and technology
- The only effective treatment option is surgery – but this needs to be undertaken early before the cancer has grown and spread into complicated anatomical areas
- The cancer is nearly always detected late meaning curative surgery is not possible. Current tumour markers show poor accuracy especially in early disease², and radiology (CT/MRI) is also poor at detecting the cancer especially early. Also, it is not always possible to distinguish benign from malignant biliary strictures, or differentiate cholangiocarcinoma from other liver tumours, such as metastases or hepatocellular carcinoma – quite apart from the prohibitive cost implications of sending rural south-east Asian hilltribes for radiological scans.

logistical, time and financial constraints, the project was limited to recruiting five cancer patients and 20 healthy controls.

Intelligent computer software was used to firstly look at the ‘multivariate’ profiles – i.e. all the metabolites present and their respective concentrations. Using two different statistical techniques, the computer was able to separate cancer from healthy controls with an extremely high degree of accuracy. Individual metabolites were then looked at which showed three significant individual metabolite alterations in our small study alone, as well as many others that didn’t reach significance (perhaps due to sample size).

This is extremely exciting preliminary work that now needs further validation. These results show strong evidence to support further work on such urinary diagnostics, but as a pilot study our work suffers from two main limitations.

Firstly, this original study had a sample size that limits our ability to draw conclusive observations and, secondly, we cannot completely discount the fact that parasites may have been interacting with the urinary metabolites. No urinary metabolic assessment with any parasites has ever been shown to show suppressions in some of the metabolites that we observed, however no previous work has looked at these parasites so we cannot discount their influence.

The Future

To correct these study limitations more cancer and control patients are being recruited in Thailand, alongside a third cohort of people infested with parasites but without cancer. Further work will compare their profiles to non-malignant pathology of the bile ducts, and compare our alterations with other documented cancers. By combining this urinary test with other markers for hepatocellular carcinoma and viral hepatitis we hope to develop a simple screening test for multiple liver pathologies, with the ultimate of screening large populations for different liver pathologies with one simple and cheap modality. In this way we hope to be able to move tangibly closer to the exciting dream of diagnosis of serious pathology by urinary assessment.

There are still barriers to be overcome outside technical development – mainly the logistics of screening rural communities, and capacity-building of healthcare services in response to a waft of new diagnoses that screening would likely present; however we feel these issues could be addressed and therefore not significantly limit efforts to improve this disease’s prognosis.

Although it is still very early days in this research, we are hoping this is a significant step towards finding an innovative way of alleviating a major disease burden in isolated and impoverished communities, which may also have relevance in more developed countries.

John would like to thank everyone who made this work possible, especially for the enthusiasm of Prof. Simon Taylor-Robinson, Dr. Shahid Khan, and to IGHI for their kind contribution and support for the ongoing research.

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John Chetwood is a 5th year medical student studying at Imperial College London. His cholangiocarcinoma project was recent winner of the Institute of Global Health Innovation (IGHI) ‘Next Generation: Global Health Innovators’ award which included £2000 for further research.

Mainly due to parasitic infestation, this cancer is overwhelmingly common in rural Thailand. Freshwater fish are carriers of these parasites and a way to become infected is through traditional fish dishes, prepared using a fermenting method instead of cooking the fish.



Commercial Surrogacy: A Priceless Commodity?



Robyn Perry-Thomas, University of St Andrews

Surrogacy is not a new idea. Neither is medical tourism. The biblical tale of Hagar, Abraham and Sarah is perhaps the first record of surrogacy in action and Ancient Greeks would travel far distances to reach Sanctuaries devoted to their Gods, in the hope of health improvement.

However, advances in reproductive technologies, communication and travel have combined to make medical tourism far more attractive and accessible. As a result, reproductive tourism in the form of commercial surrogacy is undergoing a major surge in popularity.

Commercial surrogacy is a term that describes a woman who is financially compensated – beyond expenses associated with pregnancy – for carrying the baby of another couple. Statistics regarding exact numbers of commercial surrogacies are difficult to come by, perhaps because reported numbers of IVF cycles at assisted reproductive clinics do not necessarily correlate with successful pregnancies, or possibly because such surrogacies are often thought of as controversial.

As reproductive technology such as IVF becomes more advanced and with that, more accessible, it is indisputable that incidence of gestational surrogacy is increasing. The Society For Assisted Reproductive Technology (SART) has shown that between 2004-2008 the numbers of gestational surrogacies increased by 89%¹.

With clear financial advantages to international commercial surrogacy, certain countries without regulation to the contrary – such as Ukraine and India – are

becoming hotspots for the industry. India in particular has emerged as a first port-of-call for the baby outsourcing trend currently sweeping the world². However, there are both practical and ethical objections to this emerging practice.

In particular, the psychological consequences for the surrogate mother are difficult to anticipate. Especially when the motives for entering a surrogacy contract are predominantly financial, it is unreasonable to expect a woman to accurately predict how she will handle giving up the baby. It is equally important to remember the serious and potentially fatal health consequences that the act of pregnancy itself carries.

The World Health Organisation (WHO) reported that in 2008 more than 358,000 women died from complications related to pregnancy or childbirth. Furthermore, an alarming 10 million women suffer from injury, infection or disease as a result of a pregnancy. The risks to life from surrogacy are therefore not insignificant. These risks may even be greater than those experienced in a normal pregnancy due to the higher prevalence of multiple births and caesareans associated with IVF³.

Between 2004-2008 the numbers of gestational surrogacies increased by 89%

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India – An Entrepreneur’s Paradise

As the globalisation of healthcare gains momentum, the number of fertility clinics worldwide is rising accordingly. The lack of legal complications, seemingly high availability of surrogates and relatively inexpensive nature of surrogacy in India combine to make it an attractive and attainable option for many couples. The Iswarya Women’s Hospital & Fertility Centre, has shown a 7-fold increase since 2004 (2 surrogate assisted births) to 2008 (14 surrogate assisted births). Whilst these figures may not seem particularly significant in isolation, when we remember that there are hundreds, possibly thousands of fertility clinics worldwide, the numbers add up very quickly⁴.

The Akansha Infertility and IVF clinic in Anand, India is experiencing a similar surge in popularity. The Medical Director of the clinic, Dr. Nayna Patel, is a highly educated, entrepreneurial woman. She describes with enthusiasm and unabashed pride the process by which a woman can become a surrogate in the 2009 film *Google Baby*. Patel describes commercial surrogacy simply: it is ‘one woman helping another’.

Potential surrogates at Patel’s clinic must meet strict criteria. All women should have successfully had a child previously, and be genetically unrelated to the surrogate child – although surrogates are frequently egg donors too. This acts as a precaution to prevent the women from forming strong attachments to the babies that they are carrying. However, the 1990’s Californian *Johnson vs. Calvert* case is a painful example of how, even in gestational pregnancy, a surrogate mother can develop a strong bond with the baby.

In this case, Mark and Crispina Calvert hired a surrogate, Anna Johnson, to carry their baby. IVF was used to fertilise Cristina’s egg with Mark’s sperm before implanting the resulting zygote in Anna’s uterus. The pregnancy was a success however a legal battle ensued as Anna discovered that she had formed a much stronger bond than anticipated with the child. The court found in favour of the Calverts, and Anna was left with no legal claims to the child. Anna clearly could not predict how it would feel to give up a child, and paid a steep price.

The lack of legal complications, ... relatively inexpensive nature of surrogacy ... make it an attractive and attainable option for many couples

This is especially true when the women making this decision are blinded by poverty and their need to provide basic living essentials for their families. In such cases their ability to objectively evaluate the effect of this invasive procedure, and its accompanying roller coaster of emotions, is almost definitely compromised, even if they pass ‘mandatory psychological assessments’ that are obligatory in many of these clinics⁵.

A Question of Rights

Interestingly, both critics and fans of commercial surrogacy take on the human rights shield when supporting their positions. The Universal Declaration of Human Rights (article 16) says that ‘Men and women of full age ... have the right to marry and found a family.’ Article 27 goes on to say that ‘Everyone has the right ... to share in scientific advances and its benefits’. By this reasoning alone, if the technology to have a child via surrogacy is available, then women have every right to

Definitions

Surrogacy: The act by which a woman carries a baby for a couple who are unable to do so themselves under the assumption that she will give them the baby after birth

Traditional (partial) surrogacy: The surrogate mother is artificially inseminated with the intended fathers sperm – the child will be biologically related to the surrogate

Gestational (full) surrogacy: The surrogate is implanted with an embryo via IVF and is not genetically related to the child

Altruistic surrogacy: There is no financial gain from the surrogate in having the baby although she may be compensated for expenses incurred during the pregnancy

Commercial surrogacy: The surrogate is financially compensated beyond expenses associated with pregnancy

Social mother: the mother who intends to raise the child

Intended parents: the parents who commission the surrogacy and intend to raise the child

take it up. Furthermore, in many cultures where having a child is considered a great gift and a blessing, denying a couple of this right can be seen as doing them a grave disservice⁶.

Daniel Callahan, a renowned philosopher with a special focus on bioethics, beautifully articulates the flaw in this desire to utilise technology whenever possible. The quote below, taken from his paper 'Death with dignity', illustrates an underlying principle that is perfectly applicable to our discussion here. He writes,

'[Some physicians argued that] they had a moral duty to save life at all costs. The quality of life, the actual prognosis, or the pain induced by zealous treatment, were all but irrelevant. The technological imperative to use every possible means to save life was combined with the sanctity of life principle in what seemed the perfect marriage of medicine and morality.'⁷

As Callahan implies, just because the technology to save life exists, it doesn't mean that it must be used. The same can be said for commercial surrogacy – yes, we have the technology to do it, and we may even have willing participants, but should we actually do it?

There are further ethical issues at stake. The use of human beings – both the baby and surrogate – as a commodity, and the idea of ownership, even if just for nine months, of one person by another are issues that cannot be ignored.

A Feminist Issue?

It may seem paradoxical to approach this issue from a feminist angle when you consider the fact that most of the key players are women. It tends to be women that

strongly feel the desire for a child, women who volunteer for surrogacy and women who are often the hospital directors and healthcare workers fuelling the provision of surrogacy services. In order to see why this is a feminist issue we must take the opportunity to reflect upon the reasons why women consider commercial surrogacy in the first place.

Quite often, the answer is poverty. Many women taking part in this type of surrogacy live in destitute situations where any opportunity to escape poverty is likely to be welcomed with open arms. Yet, although poverty affects men and women equally, only women can act as commercial surrogates. The decision they make is unlikely to

Quite often, the answer is poverty. Many women taking part in this type of surrogacy live in destitute situations where any opportunity to escape poverty is likely to be welcomed with open arms

be solely their own – it will be influenced by social circumstances, in-laws, husbands and maybe even their children – and yet they alone will have to face the emotional and physical consequences of becoming a surrogate. In this way women are exquisitely discriminated against.

The Law

Complications related to pregnancy can raise certain legal issues. For example, to what extent (if any) can the commissioning couple be held responsible for a surrogate death from complications during pregnancy or labour? What claims, if any, does a surrogate mother – or her relatives – have to the child?⁸

These issues are highlighted by the example of Natasha Caltabino, a British surrogate. On New Years Eve 2004, Natasha died of an abdominal aortic aneurysm within hours of giving birth to a baby boy. The Surrogacy Arrangement Act states 'surrogacy arrangements are unenforceable' so commissioning parents must legally adopt the child after birth. Following Natasha's death both her mother and the commissioning couple laid claim to the baby – who eventually went to the intended biological parents.

There is a large variation in surrogacy laws worldwide. Some countries, such as France and Germany, have a complete ban on all forms of surrogacy. Others, such as the UK, enable altruistic surrogacy only – although in the UK, reasonable expenses can be paid to the surrogate, and it is common practice for the commissioning couple to take out a life insurance policy for the surrogate.

[5] Bioethics (2009) Johnson vs. Calvert Summary. [Online] Available at: <http://www.bioethics.gr/media/pdf/biolaw/nomologia/JohnsonvCalvert_Summary.pdf> [Accessed 18 March 2012]

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India has emerged as a first port-of-call for would-be parents seeking commercial surrogates. For young women, this is seen as a route out of poverty – but is it worth it?

A more liberal approach in which both commercial and altruistic surrogacy is legal has been taken by countries including Israel and India. This inconsistency in the law globally has given rise to a number of complicated legal dilemmas that, in correlation with the increasing popularity of reproductive tourism, look set to arise more often.

Laws regulating surrogacy can be complex and hard to enforce. In light of this, as well as the psychological and potential physical damage that could be caused to the surrogate, perhaps a total ban on commercial surrogacy, including altruistic surrogacy with 'reasonable' monetary compensation, is necessary. However, it would be naive to think that such a move would have no negative consequences. The emergence of a black market is almost inevitable. The criminalisation of commercial surrogacy would leave desperate couples and potential surrogates open to exploitation by 'underground' surrogacy brokers.

Do Onto Others ...

Commercial surrogacy potentially leaves women open to exploitation, and both physical and mental scars.

One potential solution is a complete ban on commercial surrogacy internationally – however, this is probably unlikely in the near-term. Another avenue is to increasingly render commercial surrogacy socially unacceptable, probing questions of ethics and responsibility.

Laws regulating surrogacy can be complex and hard to enforce

Perhaps the answer lies in the words of the well-known philosopher Immanuel Kant:

I ought never to act except in such a way that I could also will that my maxim should become universal law.

In other words, if you wouldn't want to become a surrogate, or you wouldn't want your wife or daughter, sister or friend to do so – solely out of financial need – then how can we consider it a viable escape from poverty for any woman?

Robyn Perry-Thomas is a first year medical student at the University of St Andrews.

The Politics of Expanding Control of NTDs

Prof. Alan Fenwick OBE, Imperial College London

500 million people – two-thirds of the total population of Africa – have two or more Neglected Tropical Diseases such as Lymphatic Filariasis, Onchocerciasis, Schistosomiasis, and Trachoma and need regular treatment. In addition to illness and mortality, these infections have a significant economic impact on families, communities and even countries as a whole, and result in billions of dollars of lost productivity. NTDs help to maintain poverty.



Identified as a high impact, cost-effective and deliverable intervention, tackling NTDs through mass drug distribution has recently soared on the aid and development agenda. In fact, in January 2012, the UK Department for International Development announced an aid package totalling £245m, aiming to protect an estimated 140 million people from such parasitic infections.

An emerging success story in global health: just how did NTDs move from marginal to mainstream?



The 13 most important Neglected Tropical Diseases (NTD) include seven which can, and should, be controlled with the annual distribution of four drugs, all of which are donated by pharmaceutical companies or purchased for donation by foundations or governments. Another NTD – Guinea Worm – is close to eradication using health education and clean water supplies. Three others are protozoan diseases, which are killers but fortunately with limited distribution.

In 1986 the first large scale unlimited donation of a medication for annual distribution to those in need was made by the US company Merck Ltd, known in

UK as MSD (Merck Sharpe Dome). This commitment for Mectizan has since protected some 100 million people in tropical Africa, in particular those who live on the banks of fast flowing rivers, against severe itching and river blindness. After 25 years of regular treatment, blindness has been virtually eliminated from Africa, although the worm has not. Thus, some 80 million people still take an annual dose of Mectizan, which prevents the worm from giving birth to the live larvae that cause the itching and blindness.



In the 1990's it was discovered that the same drug Mectizan, if given simultaneously with Albendazole (again annually), would prevent the larvae being produced by the two worms that cause Lymphatic Filariasis (LF) – *Brugia malayi* and *Wuchereria bancrofti*. Albendazole was donated by GSK, and Merck extended their donation of Mectizan, so that all LF areas in Africa could receive the two drugs free of charge. In the Far East, where over

Five diseases, six worms and a bacteria, and drugs provided free of charge – where is the politics in that?

500 million people are at risk of LF, Albendazole (again donated by GSK) is given with DEC, which is an inexpensive drug with the same effect on larvae of LF. From 2012 to 2020, some 600 million treatments will be delivered annually and LF might well be eliminated by 2020.

Soil Transmitted Helminths (STH) are intestinal worms that can be easily treated with a single dose of (wait for it) Albendazole. Therefore everyone who is treated in the LF elimination programme also receives a deworming pill annually. However, globally up to two billion people have at least one of these worms, so many more need regular deworming.

Schistosomiasis, a parasitic water-borne worm, is widespread in Africa with an estimated 200 million infected. Again there is a treatment – Praziquantel. Between 2003 – 2007 this drug was purchased by the Schistosomiasis Control Initiative (SCI) at Imperial College, using funds from the Bill and Melinda Gates Foundation. Thereafter two other funders arrived on the scene and also purchased Praziquantel for donation (the philanthropic foundation Legatum and the United States Agency for International Development, USAID). In 2009 a donation commitment was made by E. Merck Serono to provide 20 million tablets a year for 10 years. A generous donation, but not enough to treat more than 8 million children; therefore in January 2012, Merck Serono decided to increase their donation incrementally to reach 250 million tablets by 2016.

Trachoma is a disease of the eyes caused by the bacteria Chlamydia. It affects about 80 million worldwide and can be controlled by an annual dose of Zithromax. The manufacturer Pfizer now donates this drug, and in 2011 an estimated 70 million doses were provided to poor countries.

Where is the Politics?

So five diseases, six worms and a bacteria, and drugs provided free of charge – where is the politics in that? Well that's where the politics starts: first of all, the

people who are infected or at risk of these infections mostly do not know that they are infected or that their future is at risk because of these infections. Therefore we have to be proactive in bringing these drugs to the people who need them. This means that we have to persuade the relevant ministries of health and education to implement a treatment campaign.

They are unlikely to have the resources to do this, so we have to bring those resources together – funding, equipment, transport, IEC materials, training material, money for per diems etc.

If the funds are coming from donations, be it from the US government, the UK government or a foundation (Gates or ENDFUND), then a political process needs to be satisfied, often involving a competitive bidding system. This then brings into conflict the very implementing agencies that previously have all worked together and collaboratively. Even the governments themselves (and in a way it is fortunate there are just two governmental donors), DFID and USAID, have to work together to ensure their donations are not duplicating efforts, but are instead working synergistically. The World Bank also provides funding directly to governments for both health and education development. In contrast to these



Mass drug administration programmes treat and prevent conditions such as lymphatic filariasis (left)





| Neglected Tropical Disease | Status | Control Strategy |
|-------------------------------------|--|---|
| Protozoan Infections | | |
| Human African Trypanosomiasis (HAT) | Over 50,000 infected in Africa | New drugs are needed |
| Chagas Disease | Increasing no. of cases found in Europe | New drugs are needed |
| Leishmaniasis (dermal and visceral) | Up to 12 million infected globally | Treatment available |
| Bacterial Infections | | |
| Buruli Ulcer | Reported in 30 countries in Africa, the Americas, Asia and the Western Pacific | Treatment with antibiotics and surgery |
| Leprosy | Most countries are below 1 in 10,000 cases | Flexible choice of treatments |
| Trachoma | 80m infected, 8m visually impaired, eliminated from Morocco | Treatment with Zithromax, part of the SAFE strategy including surgery, environmental improvement and face washing |
| Helminth Infections | | |
| Ascaris | Over 800 million infected | Need of treatment with albendazole and mebendazole |
| Trichuris | Over 600 million infected | Difficult to treat but albendazole and mebendazole reduce egg output |
| Hookworm | Over 500 million infected | Treatment with albendazole & mebendazole |
| Schistosomiasis | 200 million infected in Africa | 20% get treated annually with praziquantel |
| Lymphatic Filariasis | En route to elimination | 600 million treatments per year delivered to prevent transmission |
| Onchocerciasis | Elimination by 2020 is possible | 80 million are treated annually to prevent itching and blindness |
| Dracunculiasis | Just a few countries with isolated cases | No drugs, prevention only |

The 13 most important Neglected Tropical Diseases

conflicts for funding, the pharmaceutical companies are complementing each other's donations and working together to make the application processes for the countries much simpler. The World Health Organisation NTD department, directed by Dr. Lorenzo Savioli, now coordinates most of the donation programmes.

At present, in 2012 there are 600 million treatments for LF being delivered annually globally, with 80 million of these in Africa. There are 70 million treatments for Trachoma and 80 million against Onchocerciasis. Schistosomiasis and Soil Transmitted Helminths are the poor relations with maybe only 20% of those in need having been treated in 2011. But that is all going to change over the next 4 years as increased donations come on stream – Albendazole and Mebendazole (to deworm children) and Praziquantel (to treat 100 million children annually).

Bill Gates made a huge political gesture on January 30th 2012 by bringing together the CEO's of 13 pharmaceutical companies, several Ministers of Health from developing countries, the Director General of the World Health Organisation, a senior staffer from USAID and the World Bank. Also in attendance was the UK Minister for International

Development The Hon Stephen O'Brien who, with the CEO of Merck, made two of the most amazing commitments for NTD control, including a pledge of £245m over four years (2011 – 2015) from the UK Government which marks a five-fold increase in support for NTDS.

What is needed now is peace, prosperity and good governance in all countries in Africa so that ministries of health and education can deliver the donated drugs using funds provided by governments and foundations, and technical assistance from the likes of the Schistosomiasis Control Initiative and Partnership for Child Development at Imperial College; the Centre for NTDS, Liverpool and Sightsavers which are all part of the UK Coalition for Neglected Tropical Diseases.

All these diseases have been targeted for elimination by 2020, but politics more than anything will determine whether we can achieve these goals.

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Global Mental Health

Roxanne Keynejad, King's College London

For global health to truly deliver the overarching aim of health equality for all, it must overcome the artificial dualism separating mental from physical illness, in line with the WHO definition of health as 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.'

Globally, mental health is stigmatised and neglected, with a greater focus placed on infectious diseases, maternal and child health in the developing world and on other non-communicable diseases in the developed world. This creates an enormous treatment gap in some countries, with up to nine out of ten patients not receiving basic care.

The lack of correlation between services and disease burden, low numbers of psychiatrists and psychiatric nurses and migration of trained staff are key challenges to addressing mental health inequalities in developing countries.

Although their treatment is under-prioritised, the contribution of neuropsychiatric conditions to the global burden of disability-adjusted life-years (DALYs: years lived with disability plus years of life lost) is growing. The greatest proportion (28%) of worldwide non-communicable disease burden is attributable to neuropsychiatric conditions, with 10% contributed by unipolar affective disorder alone, and there is a clear correlation between neuropsychiatric DALYs and economic development. As lives lost to communicable diseases decline with improved sanitation, nutrition and

healthcare, the contribution of neuropsychiatric conditions to worldwide disability increases.

No Health without Mental Health

Despite the traditional separation of services for physical and mental illness, there are complex inter-relationships between the two, encapsulated in the phrase, "no health without mental health". This oft-ignored fact was discussed in depth in the Lancet's first global mental health series in 2007.

An in-depth database search published in the Lancet revealed the relationship between global mental health and broader physical health and concluded that:

Mental disorders increase risk for communicable and non-communicable diseases, and contribute to unintentional and intentional injury. Conversely, many health conditions increase the risk for mental disorders, and comorbidity complicates help-seeking, diagnosis, and treatment, and influences prognosis. Health services are not provided equitably to people with mental disorders, and the quality of care for both mental and physical health conditions for these people could be improved.¹

These authors highlight the role of stigma in the justification of ignoring mental health needs, and the isolation of psychiatric treatment from the rest of medicine, despite their evident inter-relationship. The relationship between physical and mental illness, mortality and morbidity is complex and bidirectional, affecting rich and poor countries alike.

Despite the traditional separation of services for physical and mental illness, there are complex inter-relationships between the two

Mental Health

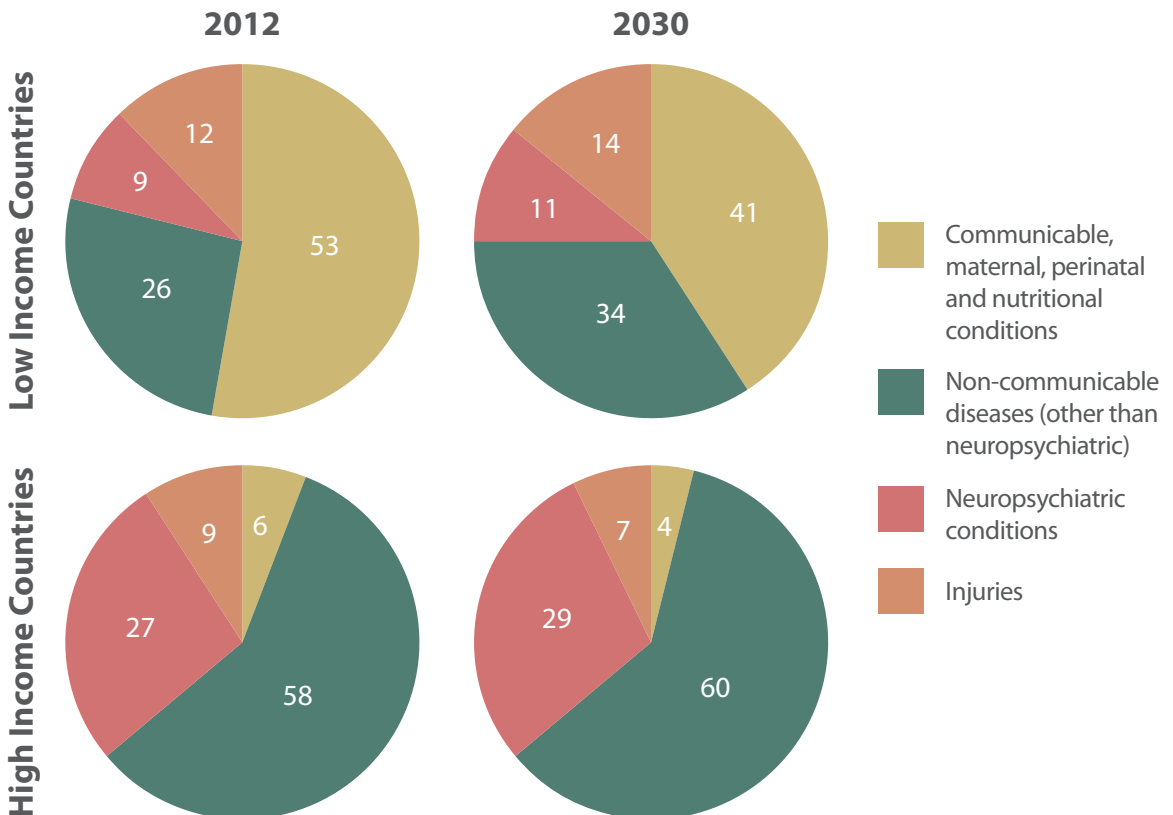
The Mental Health Foundation defines good mental health as the ability to feel, express and managing positive and negative emotions, form and maintain good relationships, cope and manage change and uncertainty and engage in learning. People in good mental health can make the most of their potential, cope with life and play a full part in their family, workplace, community and among friends.

2.6 million people were newly infected with HIV in 2009. Symptomatic HIV is associated with poor mental health via direct impact on the central nervous system, as well as via opportunistic infections and antiretroviral side effects. Crucially, depression, cognitive impairment, alcohol and substance-use disorders reduce adherence to HAART (Highly Active Antiretroviral Therapy), increasing drug resistance. HIV cannot be treated in isolation;

whilst collaborative interventions now target tuberculosis and HIV together, these must also incorporate neuropsychiatric services.

Despite the absence of mental illness from the Millennium Development Goals, global mental health plays a role in their achievement. Women have a 1.5-2.0 times greater risk of mental illness than men, mediated

Contribution of neuropsychiatric conditions to the global burden of disability-adjusted life-years (DALYs; years lived with disability plus years of life lost)



The Facts

European countries spend over 5% of health budgets on neuropsychiatric services.

70% of African countries and 50% of South East Asian countries allocate less than 1% of their budgets to mental health.

Depression, schizophrenia, bipolar disorder and dementia are associated with all-cause mortality.

1.2 million deaths are caused each year by dementia, Parkinson's disease and epilepsy.

86% of the world's 800,000 annual suicides occur in low and middle-income countries.

Suicide rates are thought to be much higher than reported, based on studies in India.

Major depression incidence is 15-30% in the first month after myocardial infarction.

Depression predicts adverse outcomes, physical and social disability post-MI.

by poverty. Mental disorders are correlated with gynaecological morbidity, including chronic pelvic pain, whilst maternal psychosis is associated with preterm delivery, low birth-weight, stillbirth and infant mortality.

Poverty and Mental Health

It is clear from the literature that the Millennium Development Goals: combating HIV/AIDS, gender equality, child health, maternal health, ending poverty, universal education, environmental sustainability and global partnership are all directly or indirectly related to improved mental health. Studies implicate the need to integrate mental health treatment and promotion into primary and secondary general healthcare, and to maximise physical and mental wellbeing in settings where psychiatrists and psychiatric nurses are in short supply.

There is evidence that the social, psychotherapeutic and behavioural support of community clubs has increased compliance, treatment completion and cure rates for

tuberculosis in India and Ethiopia. Service user networks in Zambia show how campaigning, community action and self-help in the voluntary sector can complement statutory services². For example, workers actively contact mental health service users, supporting them and their carers, targeting cultural beliefs in bewitchment and possession and social stigma. Provision of community mental health services would cost US\$2-4 per person, per year in low to middle-income countries³, a worthwhile investment given the cost of disease burden.

Through apprenticeship models and practical toolkits for well-trained and supported lay workers, there is scope to greatly expand mental health human resources to increase access to high-quality care⁴. Furthermore, lessons learned from the developing world may be transferrable to the under-provision of mental healthcare in the developed world, and may be a key force against worldwide stigma:

Non-specialist health professionals, lay workers, affected individuals, and caregivers with brief training and appropriate supervision by mental health specialists are able to detect, diagnose, treat, and monitor individuals with mental disorders and reduce caregiver burden.⁵

In the UK, moves to Improve Access to Psychological Therapies (IAPT) have led to the training of other professionals in the skills of cognitive behavioural therapy.

Similar initiatives have shown promise in developing countries including India, Pakistan and Uganda. Psychological treatments for depression, adapted to the specific community's cultural context, delivered by lay and community health workers showed significantly increased recovery rates compared with treatment as usual. These studies simultaneously addressed human resource and acceptability barriers to accessing

psychological therapies in the developing world⁶. Their encouraging results are attributable in great part to rigorous training, support and supervision provided, and

Women have a 1.5-2.0 times greater risk of mental illness than men, mediated by poverty. Mental disorders are correlated with gynaecological morbidity, including chronic pelvic pain, whilst maternal psychosis is associated with preterm delivery, low birth-weight, stillbirth and infant mortality



should not be seen as alternatives to the provision of highly skilled psychiatrists, psychologists and psychiatric nurses, indispensable for the care of severe psychiatric illness⁷.

No Stigma in Mental Health

The Movement for Global Mental Health's call for action focuses on five key recommendations. First, that all governments deliver a national mental health service and second, that international donors prioritise mental health in resource allocation to low and middle-income countries. Third, that US\$2-4 per person be the minimum budget allocation for mental healthcare and fourth, that budgets are transparently monitored. Finally, the need for research prioritisation of global health and dissemination of findings. In a promising move, the UK Government recently unveiled a doubling in funding for research into dementia to £66 million by 2015.

These proposals make economic as well as clinical sense. Two systematic reviews found that mental health interventions are associated with improved financial outcomes: evidence that neuropsychiatric conditions must be a priority of development interventions⁸.

Importantly, pervasive stigma and discrimination towards mental illness continues to cause widespread human rights abuses towards people with

neuropsychiatric disorders worldwide. The UN Convention on the Rights of Persons with Disabilities advocates a collaborative approach to address stigma. This should involve all stakeholders in education, empowerment and accountability, which have been instrumental in reducing stigma surrounding HIV and other disorders:

This begins with educating all parts of society, including all sectors of government, health and mental health professionals, the media, and of course people with mental and psychosocial disabilities and their families about mental health and human rights [...] Civil society must be enlisted as advocates and agents for change, holding governments accountable for meeting their obligations

[...] To rectify this historic and ongoing neglect and mistreatment, it is essential to create clear benchmarks or indicators of tangible progress, with rigorous monitoring and assessment at the state and international level.¹⁰

Stigma must be addressed if governments are to invest precious resources in global mental health and for society to support its prioritisation. Four years on, the movement has seen progress in its recommendations. The second Lancet series in 2011 outlines this, but stresses the continued need to implement these goals. Health and social policy must use the existing strong evidence base to support critical investment in developing countries. Here, the collaborative ethos of global health can be extremely effective, integrating multidisciplinary clinicians, lay persons, service users and carers in a highly motivated workforce. Only through this unified approach can global healthcare deliver its goal: complete physical, mental and social well-being, for all.

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