

Sarah Jewitt (School of Geography, University of Nottingham, University Park, Nottingham, NG7 2RD, United Kingdom)

Applied Geography **Volume 31, Issue 2, April 2011, Pages 761–769**

Poo Gurus? Researching the threats and opportunities presented by human waste.

Abstract

There is huge geographical variation in the extent to which excrement represents a threat to human and environmental health. In the UK, we tend to think little of such risks. By contrast, 52% of all people in Asia have no access to basic sanitation and 95% of sewage in developing world cities is discharged untreated into rivers, lakes and coastal areas where it destroys aquatic life, reduces the potential of these ecosystems to support food security, facilitates the transmission of diseases and has a significant economic impact in terms of working days and earnings lost due to ill health. At the same time human excrement represents a resource that could be better utilized to promote human livelihoods and improve environmental quality through use as manure and as a source of biogas energy. This paper seeks to provide an overview of the importance of human waste (as both a threat and an opportunity) in different spatial, historical and cultural contexts and to highlight potential areas of interest for applied geographical research in future.

Key words

Excreta, threat, opportunity, humanure, ecosan, biogas.

1. Introduction

According to the United Nations (2008a), a child dies every 20 seconds due to a lack of access to clean water and sanitation; that's 1.5 million preventable deaths each year. One of the key causes of these deaths is exposure to pathogens associated with human excreta, but huge spatial inequalities exist in the extent to which such waste threatens human, environmental and economic health. In the UK, we think little about such threats except in terms of a general consciousness of the need to wash our hands after going to the toilet and a broader awareness of the environmental problems associated with sewage treatment and disposal. By contrast, 52% of all people in Asia have no access to basic sanitation and 95% of sewage in developing world cities is discharged untreated into rivers, lakes and coastal areas where it destroys aquatic life and greatly reduces the potential of these ecosystems to support food security (Esrey et al 1998; Hannan and Andersson 2001b; Watson and Zakri, 2008). Globally, over 200 million tonnes of human waste go uncollected and untreated each year (UN 2008b).

In addition to fouling the environment, this facilitates the transmission of diseases such as typhoid and cholera and has a significant economic impact in terms of the cost of medical care plus working days and earnings lost due to ill health and tourism (WaterAid, 2009a). In India alone, 73 million working days are lost each year as a result of waterborne illnesses (Wherever the Need 2008). World Bank data for India and Nepal, meanwhile,

estimate that these countries lose USD 238 million and 5.7 million per year respectively in tourism revenues due to a perception of poor sanitation (Arby, 2008a). The UN (2008b, p. 1) also emphasizes the economic costs of poor sanitation with its estimate that every dollar invested in sanitation improvements “*generates an average economic benefit of \$7*” whereas the “*economic cost of inaction is astronomical*”. To meet Millennium Development Goal 10 (which seeks to halve, by 2015, the 2.6 billion people who currently lack access to basic sanitation) and address the threat that human waste (plus the profligate use of potable water for sanitation purposes) represents to environmental quality and ecosystem functions/services globally, there is an urgent need to develop improved sanitation and sewage treatment systems (Esrey et al 1998; Rockefeller 1998; Rosemarin 2008; George 2008; UNDP 2008; Watson and Zakri 2008). According to the WHO (2006, p.7) many developing countries need to make significant policy changes and innovations in “*technical choices, financial mechanisms, information and awareness raising and institutional responsibilities ... if this challenge is to be met*”.

On the other hand, human excreta also represent a resource that could be better utilized to promote environmental quality, meet human livelihood needs and generate economic benefits. One of the most obvious examples is the recycling of ‘humanure’ for agriculture which can provide environmental as well as economic benefits (Duncker, et al, 2007; Esrey et al, 1998; UN 2008b; UN, 2008d: Price, 2009; GTZ, 2010) but other opportunities abound. Fuel derived from human waste (notably biogas) has a number of environmental advantages as well as representing a potentially attractive investment; especially when the prices of conventional energy sources rise (ter Heegde and Sonde; 2007; Guardian, 2008; Thames Water, 2009; Abassi and Abassi, 2010; Defra, 2010; Gasworld, 2010; Lohri et al, 2010). According to Rodriguez and Preston (2007, p. 2) using excrement to produce biogas can “*play a pivotal role in integrated farming systems by reducing health risks, facilitating control of pollution and at the same time adding value to livestock excreta through the production of biogas and improved nutrient status of the effluent as fertilizer for ponds and crop land*”.

Yet despite the global significance of sanitation issues and the use/management of human excrement more generally, contemporary applied geographical research on spatial and temporal variations in the use and management of human excreta is quite hard to find.¹ Although geographers have carried out some fascinating work on animal manure as a pollutant (Lowe et al, 1997; Seymour and Clark, 1991; Ivey et al, 2006) and a fertilizer (Chisholm, 1961; Baker, 1973; Widgren, 1979; Adams and Mortimore, 1997; Harris, 1999; 2002; Harris and Yusuf, 2001; Matless, 2001; Robbins, 2004; Jewitt and Baker, 2006; Baker and Jewitt, 2007; Grantham, 2007; Ingram, 2008; Williams, 2008), only a small number of geographers have been actively engaged in research that deals with human waste; and most of this work deals with it in somewhat tangential (though nonetheless important) ways. Examples include research within medical geography on faecal transmission routes (Anderson, 1947; May, 1950; 1952; Howe, 1963; 1980;

¹ Black and Fawcett (2008) point out that the ‘great distaste’ surrounding human waste topics has tended to result in its neglect as academics have tended to shy away from conducting research on excrement and “*politicians, celebrities and philanthropic corporate donors [are] willing to couple their names only to delightful water, rarely to nasty shit*” (ibid, 75).

Haviland, 1982; Haggett, 1994; Rupke, 2000; Smallman-Raynor et al, 2001; 2004a; 2004b; 2006; Cliff et al, 2004; 2008; Abrahams, 2006), cultural and historical geographies of agriculture, organicism, sanitation and cholera (Bacon 1956; Smith 1975; Kearns 1984; 1989; 1991; 2000; Sheail 1993; Colten 1994; Goddard 1996; Matless, 2001 Gandy, 2005; 2008; Krantz, 2006; McFarlane, 2008a) and wider theoretical conceptualisations of dirt (Krantz 2006; Sibley 1995; Cresswell 1996; 1997; Campkin and Cox 2007; Cox 2007; Holloway et al 2007). Research that deals more directly with human waste is even less widespread although empirical work on 'watsan' (water and sanitation) issues in the global South (Andersson, 2001; Desai, 1995a, 1995b; Gandy, 2008; Giles & Brown, 1997; McFarlane, 2008a, 2008b; O'Hara, Hannan, & Genina, 2007; Jewitt and Labhsetwar, 2009; Swyngedouw, 2004, Swyngedouw, Kaiko, & Castro, 2002) and research on the analysis, modelling and prediction of water and beach contamination by sewage and other pollutants (Reeves and Patton, 2005; Kay et al, 2007; Collins and Anthony, 2008; Rahman, 2008; Anayah and Almasri, 2009) demonstrates the importance of applied geographical research on these topics. And in combination with wider geographical research on environmental quality, this work has provided some important monitoring, modelling and participatory resource management tools for improved landuse planning and environmental management which have great relevance for understanding and managing the threats and opportunities created by human excreta (He et al, 2006; Ivey et al, 2006; Wang et al, 2007; 2008; Collins and Anthony, 2008; de Graaff, 2008; Maconachie et al, 2008; Zeilhofer and Topanotti 2008; Rahman, 2008; Anayah and Almasri, 2009; Collins et al, 2009; Dewan and Yamaguchi, 2009; Kamusoko et al, 2009; Maantay and Maroko, 2009; Rhoades et al, 2009; Velázquez et al, 2009; Mishra and Griffin, 2010).

Given the importance of human waste as an influence on human and environmental health, this paper argues for a more coherent emphasis on such issues within applied geographical research and highlights a few topics for potential study that would enable geographers to apply their expertise outside the academy thus satisfying recent demands for greater relevance in geographical research (Cloke 2002; Gregson, 2003; Kitchin and Hubbard 1999; Pain 2003; Pain, 2004). Particular attention is drawn to the (temporally fluctuating and regionally varied) tensions and ambiguities that exist between the status of human excrement as a threat to human/environmental health and as an important resource (in the form of 'humanure', ecological sanitation and 'excrement to energy') for human livelihoods. Examples are drawn from both the global North and South.

2. Dirt pollution and taboo: insights into the spatial and cultural boundaries surrounding human waste.

The anthropological work of Mary Douglas (1966) is particularly valuable for understanding ideas of human excreta as a threat and she is highly sensitive to space in her analysis of how concepts of dirt, pollution and taboo enable different cultures to construct boundaries and identify (real and symbolic) spatial limits that enable them to feel secure and in control of their environment. Other theoretical perspectives that focus specifically on human waste include the work of Laporte (2000), Poovey (1996) and

Hawkins (2006); all of whom highlight geographical tensions over the (private) production and (usually public) management of excreta.

In terms of identifying policy-relevant research agendas for geographical research on human waste, the inherent spatiality of Douglas's work offers an important theoretical framework for the development of interdisciplinary geographical perspectives that can draw together critical academic research on excreta and more applied approaches to the threats and opportunities presented by it. Some exciting insights into the types of theoretical work that could be done can be found in Campkin and Cox's book entitled *Dirt: New geographies of cleanliness and contamination* (2007). Building upon Mary Douglas's work along with Kristeva's (1982) theory of abject matter and Miller's (1997) 'anatomy of disgust, Campkin and Cox examine the conceptualisation of dirt and cleanliness in different temporal and spatial contexts and investigate how these find expression within (and influence the arrangement of) different urban and rural spaces. They consider dirt "at a theoretical level, but also as that which slips easily between concept, matter, experience and metaphor" (p.1). Yet despite the book's emphasis on "the spatiality of dirt and cleanliness" (ibid) and how understandings of these concepts "are located within and constitutive of space and social relations" (ibid), only a few of the chapters are actually written by geographers.

Nevertheless, Campkin and Cox do identify important opportunities for "interdisciplinary spatial enquiry" (70) on dirt that could form the basis for future geographical research on human waste more specifically. Quoting William Cohen, they show how "filth represents a cultural location at which the human body, social hierarchy, psychological subjectivity, and material objects converge. Standing at a theoretical crossroads, filth is at once figurative and substantive" (Cohen 2005, viii cited in Campkin and Cox 2007, p. 6). They also highlight contrasts in conceptualisations of dirt between rural and urban spaces and show how "theoretical work on dirt has in the main remained distinct from literature on its materialities" (p. 7) in terms of cleaning practices, or environmental histories of urban infrastructural development, waste and sanitation management: linkages that geography's interdisciplinary perspectives are well placed to explore.

3. Dealing with the threat of excrement.

Although human disgust for excrement is fairly universal, the sanitation systems used to dispose of it have huge variations both geographically and historically. Regional variations often reflect important cultural differences in defecation and anal cleansing practices as well as a broader history of the region's development in terms of toilet design, placement and materials used (Gregory and James, 2006). While the aversion of humans to their own excreta has historically been a major help in limiting the spread of disease, it was not until the late nineteenth century that the linkages between bacteria and disease were fully understood (ibid). Most of the diseases spread by human waste are associated with faeces that contain germs, eggs, parasites and pathogens. These can cause a wide range of illnesses including diarrhoea, malnutrition and mineral/vitamin deficiency. When pathogen-infected faeces reach the wider environment, they quickly contaminate fluids (drinking and cooking water) and food (via human flies or human

hands), thus exposing a large number of people to infection and disease. Wherever newly infected people defecate, a new cycle of infection, contamination and re-infection begins (Esrey et al, 1998). Regular use of the same sites for open defecation brings people into more direct contact with parasites and increases the chances of cross contamination (Wherever The Need, 2008).

For many of the 2.6 billion people who currently lack access to basic sanitation², open defecation is the norm: a situation that facilitates the spread of disease due to poor understandings of the health risks associated with human waste. For those lucky enough to have access to sanitation, the most widely used systems consist of either ‘flush and discharge’ or ‘drop and store’ arrangements (Esrey et al 1998) but both can create large financial and environmental burdens, especially in developing world cities where sewage treatment facilities are underdeveloped (UNDP, 2008). Pathogens, nutrients, drugs, hormones and pollutants that are flushed into rivers, lakes, or oceans “*lead to loss of fresh water, food insecurity, destruction of soils, and loss of biodiversity on land as well as in marine environments, global warming and depletion of ozone*” (Esrey, 2001, p. 4).

Water shortages create additional constraints for many of the 2.6 billion people that lack access to basic sanitation as “*the means by which most of them dispose of their excreta now, or could dispose of it in future, is entirely separate from their water supply: there is literally no connection*” (Black and Fawcett, 2008, p. 8). In twenty years time, the additional two billion or so urban dwellers living within arid and semi-arid areas of the global South are likely present a real challenge for conventional water-based sanitation systems which typically use 15,000 litres of water per capita/year (Esrey et al 1998; UNDP 2008; Watson and Zakri 2008).³ This has led the Hannon and Andersson (2001) to argue that inappropriate sanitation can be worse than no sanitation at all “*particularly in the case of sanitation approaches which use scarce freshwater resources and risk contaminating water sources*” (p. 1).

As George (2008) points out, sanitation problems are not restricted to the global South and are often more widespread than we might expect in countries with seemingly well-organized sewage treatment methods. In August 2005, 600,000 tonnes of sewage were discharged into the River Thames, killing fish and causing a stench reminiscent of the ‘great stink’ of 1858. Subsequent inquiries revealed that Thames Water discharge sewage in the Thames around 60 times per year through combined sewer overflows (George, 2008). Nutrient rich effluent continues to reach water bodies and cause eutrophication while sewage sludge contains a wide range of toxic materials (Rockefeller 1998; Rosemarin 2008; George 2008).

² Satterthwaite (2003) questions official figures on access to water and sanitation suggesting that they seriously under-represent the numbers of people that have access to ‘safe’ water and ‘improved’ sanitation in any meaningful sense.

³ The small amount of faeces contained within this water then goes on to contaminate a further 15-50000 litres of ‘grey water’ (Esrey et al 1998) which in most parts of the global South is released, untreated, into surrounding water bodies and the problem is shifted downstream to poorer communities that are unlikely to complain (Esrey 2001).

London is not exceptional, however, as many other 'developed' countries have similar sanitation systems (Hawkins, 2006). In the USA, the Environmental Protection Agency (EPA) noted 40,000 sewage outflows in 2001 while New York discharges 4% of its sewage into its harbour (George, 2008). According to Rosemarin (2008), only about 80 major cities in the EU have advanced sewage treatment systems with the levels of treatment coverage being around 40% in Belgium and Portugal and 60% in Greece, Poland and Italy.

Even where sewage treatment systems are widespread, human waste still represents a significant environmental threat. Primary and secondary treatment of sewage often fails to treat industrial pollutants or to prevent nitrate and phosphate rich effluent reaching water bodies and causing eutrophication. The dehydrated sludge that results from such processes contains a wide range of toxic materials including heavy metals, organochlorine oestrogen mimickers, radioactive material from hospitals, and phenols (Rockefeller, 1998).

The disposal of this sludge has become a growing problem in the USA and the UK since ocean dumping was banned in the 1990s⁴. Rockefeller (1998) provides a fascinating account of political and economic imperatives taking advantage of cultural ambivalence towards excrement. She describes how environmental organisations joined the Environmental Protection Agency in promoting the disposal of sewage sludge (renamed beneficial biosolids) on farmland and gardens as a healthier and more environmentally sound 'organic' alternative to chemical fertilizer. This 'beneficial reuse' arrangement suited taxpayers and the waste industry as it represented a cheap means of sludge disposal and suited farmers who obtained fertilizer plus free lime which was given to maintain soil pH above 6.5 and allow it to bind up heavy metals.

Rockefeller is very critical of this practice stating that sewage sludge has little nutrient value as most of the nitrogen is lost during sewage treatment and disposed along with the wastewater. By contrast, heavy metal concentrations are very high and sewage sludge also contains complex mixtures of chemicals which have much greater potential to cause environmental health problems than when present in isolation. But alternative sewage treatment methods are very expensive. A 2001 estimate of the cost of achieving full compliance for sewage in the EU by 2010 was \$150-215 billion, while in the USA, pollution control between 2001 and 2021 is likely to cost \$325 billion, with \$200 billion for treating sanitary overflows (Esrey et al, 2001). So given the difficulties of cost and compliance in Europe and the USA, it is hardly surprising that slow progress is being made towards Millennium Development Goal sanitation targets in the global South (Rosemarin, 2008).

To address these problems, less developed country governments are faced with the choice of expanding existing centralized sanitation and sewage treatment systems or seeking alternative solutions that make better use of human waste and create fewer environmental

⁴ In the UK, untreated or raw sewage sludge cannot be applied to agricultural land although conventionally treated sludge can be applied to grassland or forage crops so long as harvesting doesn't take place for 12 months (Defra, 2009a).

problems (Esrey et al 1998). Rockefeller (1998) highlights the need for interdisciplinary research on the technical feasibility and social acceptability of two very different approaches which geographers may be well placed to contribute to. One involves systems for reducing the volume of sewage sludge sent for processing through ‘sewer avoidance’, separation at source and the use of on-site remediation methods such as composting toilets and reed beds. The other is more concerned with ‘waste to energy’ approaches that dispose of sewage sludge using technologies such as gasification and (although not mentioned by Rockefeller) anaerobic digestion.

4. Human waste as a resource: ‘where there’s muck there’s brass’.

In addition to offering exciting opportunities for empirical research on alternative human waste management systems in different socio-cultural contexts, these two approaches demand improved understandings of whether (and how) local taboos surrounding excreta change when it is presented as a resource rather than a threat. Historically, there has been a long (and often cyclical) association between excrement and money which has resulted in widespread “*human ambivalence to bodily wastes and discontinuity in our systems for dealing with them*” (Laporte, 2000, p. 32) and which has succeeded, at times, in tempering human attitudes towards excreta. Emphasis placed by Roman physicians on the diagnostic value of examining human waste, for example, underwent a revival in Europe from the sixteenth to nineteenth centuries and currently features in a popular British television programmes on diet and healthy eating. In ancient Rome as well as in seventeenth and nineteenth century Europe, human faeces were commonly regarded as having purifying, healing and beautifying properties (Laporte, 2000); while such uses are widely regarded as disgusting today.

4.1 Humanure: transforming filth into food.

Even the use of human waste as an agricultural fertilizer has gone in and out of fashion in the agricultural literature with Europeans often demonstrating a more ambivalent attitude towards their own excrement than East Asians who have made more consistent use of sewage as agricultural manure (Rockefeller, 1998; Esrey et al, 1998)⁵. Although Pliny’s *Natural History, Book XXVII* stated that “*human excretions are the best possible fertilizers*” (Laporte, 2000, p. 152), it received relatively little attention from scholars until the fourteenth century when Crescentius of Bologna first published his *Opus ruralium commodorum* in 1307. According to Laporte, “*the symbolic equation of money and shit*” (Laporte, 2000, p. 33) was formally registered when the *Opus* was translated into French, in 1532, under the title “*Prouffits campestres et ruraulx*”. The value of human waste as a fertilizer was again ‘rediscovered’ in nineteenth century France as the hygienists’ movement emphasized the superiority of human excrement and physicians urged agricultural communities to “*incite serious contemplation amongst growers in a region whose agricultural fame rests on the very rational use of human secretions in their*

⁵ The use of human waste as a crop fertilizer has a long history in China and the Japanese implemented a system of recycling human and animal manure for agriculture in the twelfth century. In China, traditional squatting slabs were often designed to divert urine so that it could be collected for use as a fertilizer (Esrey et al, 1998). As recently as the 1950s, around 90% of China’s human waste was put on agricultural fields, making up a third of the total fertilizer used (Hart-Davis, 1997).

most natural state” (Bertherand 1858, quoted in Laporte, 2000, p. 120). Indeed, a 1918 Parisian ordinance that allowed the discharge of disinfected sewer and cesspit waste onto public streets was denounced by certain hygienists for squandering this precious resource (Laporte, 2000).

In England, too, efforts were made during the nineteenth century to transform ‘filth into food’ (C. Krepp 1876, cited in Goddard, 1996: 277) by carting sewage from urban to rural areas where it could be used as an agricultural fertilizer. Sewage irrigation was also attempted but storage difficulties and transport costs made animal manure more competitive as a fertilizer (Goddard 1996). In the twentieth century, meanwhile, similar ideas were emphasized by organicists such as Picton (1946), Balfour (1943) Howard (1940) and Howard and Wad (1931) who argued that when detached from “*associations of dirt, animal and human dung becomes something to care for and return to the land in properly composted form*” (Matless, 2001, p. 368).

Although Douglas (1966) and Cohen recognize that “*contradictory ideas – about filth as both polluting and valuable – can be held at once*” (Cohen, 2005 xiii cited in Campkin and Cox 2007, p. 73) many subsequent writers have, according to Campkin and Cox (2007, p. 76), tended to “*polarize the binary between ‘dirty’ and ‘clean’*”. Yet these ambiguities offer some fascinating opportunities for empirical and policy-relevant research on the socio-economic, cultural, political and environmental factors likely to promote a shift in the use and management of human excreta in different spatial contexts.

4.2 Ecological sanitation: a more rational use of human secretions?

The adoption of on-site ‘composting’ or ‘ecological sanitation’ (ecosan) systems in different geographical contexts indicates how positive associations between sanitation and fertilizer production or income generation can sometimes promote quite significant changes in attitudes towards (and practices surrounding) human excreta. In Sweden, for example, composting toilets have become quite popular as sanitation and waste management systems in holiday cottages, despite their users being accustomed to conventional ‘flush and discharge’ systems in their main homes (Esrey et al, 1998). Even more significant behavioural changes have been achieved in Sweden’s Tanum Municipality, where the local government encourages the installation of ‘urine diversion’ arrangements in new homes which direct urine into tanks for collection by local farmers who spray it on their crops using mechanized equipment. This initiative forms part of an effort by Tanum’s local government to meet the Swedish Parliament’s environmental quality objectives which include zero eutrophication and flourishing lakes, watercourses and coastal areas (UNEP, 2010). Indeed, most of the nitrogen content (and fertilizer value) of human waste is found in urine with an average adult’s annual production containing 4 kg of nitrogen, 0.4 kg of phosphorous and 0.9 kg of potassium (Esrey et al, 1998). According to Esrey et al, (1998) Sweden’s total annual urine production contains 15-20% of the amount of nitrogen, phosphorous and potassium applied as mineral fertilizer in 1993.

A number of simple ecosan systems have also been developed for use in the global South where they can simultaneously provide sanitation and income generating opportunities

based on the sale of compost or the provision of nutrients for gardening/agricultural activities (Esrey et al 1998). In recent years, ecosan has been strongly supported by the UNDP which emphasizes the role that human waste can play in reducing poverty and addressing soil fertility decline. Described as a “*closed-loop ecosystem approach to the management of human excreta*” (Esrey 2001, p. 2), ecosan offers environmentally and economically appropriate sanitation as it requires neither water for flushing nor drains for excrement removal. According to Hannon and Andersson (2001: 4) whose views have been adopted by the UNDP, ecosan can:

impact positively on food security through better management of scarce water resources and contribute to health through reducing transmission of disease and increasing nutritional intake ... The establishment of an ecological sanitation system can create opportunities for local entrepreneurs to design and build toilets as well as provide training on the building of the toilets and the use of the end product, creating further income generation potential. In addition, these systems foster decentralized management systems, with potential for empowering people, providing for local livelihoods and enhancing community cohesion (p. 4).

Ecosan systems also have distinct benefits for women as they significantly reduce the drudgery of water collection associated with pour flush toilets. Female ecosan users in Zimbabwe appreciate the safety and convenience of these systems compared to pit latrines which have to be built further from the house (Hannon and Andersson, 2001).

In addition to producing pathogen-free compost in around 6 months (Esrey et al, 1998), ecosan systems that divert urine provide an important source of free fertilizer as the 4-500 litres of urine that each adult produces annually “*contains enough plant nutrients to grow 250 kg of grain, enough to feed one person for one year*” (Esrey et al 1998, p. 75). In Mexico, dehydrating toilets have been very useful in addressing soil fertility problems in the high Andean region of Cotopaxi. In Mexico City, recycled urine and faeces from eco-toilets are used to grow household vegetables that have substantially improved the nutritional status of participating households (Esrey et al, 1998).

Effective pathogen die-off can also be achieved in composting toilets, many of which do not have urine diversion systems. Such toilets still have important advantages over conventional flush and discharge technologies as they save water, prevent the contamination of soil and water resources downstream and do not require expensive additional infrastructure such as water for flushing, sewage pipelines and sewage treatment plants (Esrey et al, 2001). In addition, much has been learned from the Chinese about how to improve the effectiveness of ‘dry conservancy’ since such techniques lost the competition with water-borne sanitation in the nineteenth century (Black and Fawcett, 2008).

Despite these advantages, the deeply rooted emotions and taboos associated with human waste often occlude rational responses to its disposal, handling and re-use. Unlike flush and discharge systems, ecosan does not allow human waste to disappear into the public domain where it becomes somebody else’s problem (Hawkins, 2006), but retains it to be dealt with; albeit in a far less offensive form. Unsurprisingly, the extent to which this is considered acceptable varies greatly from place to place and between ethnic, socio-economic and cultural groups: a situation that limits the widespread adoption of ecosan systems where preferences for ‘flush and discharge’ systems are pronounced (Jewitt and

Labhsetwar, 2009). And as Black and Fawcett (2008, p. 132) point out “*If consumer demand is to be the driver for sanitary take up in untoileted areas of the world today, water is not going to be banned from the pan or U-Bend any time soon*”.

As geographers have discovered in relation to other ‘top down’ development interventions (Jewitt and Baker, 2006; Baker and Jewitt, 2007), attempts to impose unwanted change – even if it does provide wider environmental or health benefits - are likely to meet with resistance. Consequently, efforts to reduce the threats and maximise the benefits associated with human waste must be willing to adapt to locally-specific cultural preferences as well as wider socio-economic, political and environmental conditions (Gandy, 2008; McFarlane, 2008a). This is important in both the global North and South, but especially so in the latter given the greater environmental, health and economic impacts of the sanitation crisis there. Black and Fawcett argue that efforts to promote improved sanitation systems have to “*capture the imagination of consumers as a life-improving benefit...This requires a cultural revolution, not only among potential consumers, but among sanitary engineers, bureaucrats and politicians*” (p. 202). Perhaps more applied geographical research on this topic could help to achieve such a cultural revolution?

4.3 Excrement to energy.

In many areas of the world, human waste is used as a source of energy. In old Yemeni towns such as Sana’a, dried human faeces have been used as a heating fuel for hundreds of years (Esrey et al, 1998). Biogas derived from the anaerobic conversion or digestion of animal and human waste also has a long history of use as a source of household energy in the global South (Dutta et al, 1997). According to Li and Mae-Wan (2008), biogas was used as long ago as 10 BC to heat bath water in Assyria while the first anaerobic digester to produce biogas from waste was built in a leper colony in Bombay in 1859 (GTZ, 2010). Nowadays, biogas digesters are widely used for energy production in many parts of the global South world with China having been a leader in the field since the late nineteenth century (Li and Mae-Wan, 2008).

Biogas methane has a wide variety of uses including the provision of cooking and heating gas, electricity, vehicle fuel and ‘mains’ gas when processed and introduced into natural gas pipelines (Dutta et al, 1997; Energy Saving Trust, 2008; Guardian, 2008; EREC, 2009; Defra, 2010). It can also be used to make methanol and helps to prolong the storage of fruit and grain by inhibiting metabolism and killing harmful insects, mould and bacteria (Li and Mae-Wan, 2008).

Even greater benefits can be achieved where biogas units are directly linked to farm, sewage and municipal waste streams as part of a broader waste management strategy (Guardian, 2008; Defra, 2009a; 2009b; 2010; Thames Water, 2009; Gasworld 2010; Taglia, 2010). In China, anaerobic digestion is used widely for managing sewage and livestock waste which currently pollutes over 10 million hectares of farmland (Li and Mae-Wan, 2008). When combined with China’s annual production of night soil, this ‘waste’ could theoretically generate 130 billion m³ of methane (equivalent to 93 million tonnes of coal) as well as reducing the proportion of waste going to landfill (*ibid*).

In recent years, increasing efforts have been made in the global North to produce biogas from the methane produced at sewage plants. In Stockholm, the Bromma waste water plant produces around 10,000 tons of sewage sludge annually which is treated under anaerobic conditions to produce biogas for use in vehicles. The remaining biogas sludge is used in agriculture as a soil conditioner (Welsh School of Architecture, 2008). Biogas produced at Heidelberg's municipal sewage treatment works, meanwhile, is used to generate electricity and German engineers have developed a new processing system that generates biogas within five days. A third of the electricity generated from this biogas is used to power the plant while the rest is sold to the national grid (Environmental Data Interactive Exchange, 2008). Although the UK has tended to lag behind the EU in waste to energy technologies (Guardian, 2008), recent initiatives by DEFRA (2010), Thames Water (2009) and Gasworld (2010) illustrate a growing trend in the use of anaerobic digestion to process sewage, food and agricultural waste into biomethane (for use in the national gas grid), 'green electricity' and compressed biomethane for vehicle use.

At a smaller scale, biogas derived from human and/or animal waste can help to address household energy shortages in the global South by providing an alternative to wood or other biomass fuels. This is particularly important in areas where deforestation is a problem and the collection of wood fuel is an increasingly difficult and tiresome task. According to Li and Mae-Wan (2008, p. 1), a 10 m³ biogas digester "*can save 2000 kg of fuel wood, which is equivalent to reforesting 0.26-4 ha*". If burned as a cooking fuel, dung-derived biogas can also help to reduce the drudgery of biomass fuel collection as well as the 'indoor air pollution' (Bruce et al 2000; Venkataraman, 2010) associated with biomass fuel because biogas burns without smoke. Women and children are the main beneficiaries of biogas adoption as they are freed from the hazards and discomfort of cooking over smoky fires as well as from the drudgery of collecting cooking fuel, cleaning smoke-blackened cooking pots and disposing of animal dung (Reddy et al, 1995; Shailaja, 2000).

In areas where cultural taboos surrounding human excrement permit the resulting gas to be used as a cooking/lighting fuel, it can also help to address sanitation problems as well as household energy shortages (Santerre and Smith, 1982; GTZ, 2010; Lohri et al, 2010; Sinha and Kazaglis, 2010). In rural areas, anaerobic digestion has the added advantage that it produces a liquid or semi-solid slurry that can be used as a fertilizer for crops or as fodder for pigs and fish (Defra, 2009b; GTZ, 2010). Biogas slurry is usually a good source of major crop nutrients (nitrogen, potassium and phosphorus) as well as micronutrients and trace elements (Reddy et al, 1995; Mae-Wan, 2008).

In addition to providing clean energy (and helping to reduce the production of black carbon associated with the burning of biomass fuels),⁶ the re-integration of human waste or biogas sludge into soil systems can help to address global warming by reducing methane emissions, promoting plant growth and sequestering carbon through

⁶ Venkataraman et al (2010) estimate that in India alone, the provision of clean energy sources to all households that currently use traditional cooking stoves would prevent 570,000 premature deaths, avoid over 4% of India's greenhouse emissions (worth over US\$1 billion on the international carbon market) and reduce black carbon emissions by a third.

photosynthesis (Dutta et al, 1997; Mae-Wan 2008). According to Esrey et al (1998, p. 76), the integration of sanitized human waste or biogas sludge into the soil enhances:

soil fertility, increasing plant growth and hence the amount of CO₂ pulled from the atmosphere through photosynthesis. A modest doubling of the amount of carbon in non-forest soils, from the currently low level of 1% (as a result of erosion) to 2% over the course of 100 years would balance the net annual increase of atmospheric carbon over this time.

At the same time, greenhouse gas emissions from biogas production are lower than for many competing fuels. According to the Energy Saving Trust (2008), the biogas used to fuel vehicles produces 95% less CO₂ and 80% less nitrous oxide than diesel as well as having no particulate emissions and there is enough of it available to fuel half the UK's HGV fleet. There are also arguments to suggest that biogas use creates a carbon reduction of more than 100%, as "*the organic matter would have naturally put methane, a greenhouse gas 21 times more potent than carbon dioxide, into the atmosphere. Instead the methane is converted into carbon dioxide*" when burnt in vehicle engines or captured at sewage works or landfill sites (Energy Saving Trust, 2008, p. 1).

The implications of this are even more significant in the global South. According to Mae-Wan (2008), the methane flux from exposed biogas slurry is 3.92 mg/m²/hour compared to 10.26 mg/m²/hour from compost in rice fields, which means that developing countries could use biogas to mitigate methane and obtain carbon credits under the Clean Development Mechanism. In addition to conserving forests, providing clean household energy and a good soil conditioner/fertilizer, each of Nepal's working biogas digesters prevents the emission of five tonnes per annum of CO₂ equivalents; a saving that is worth over US\$5 million.

The recognition of these benefits by policy makers is reflected in the fact that Nepal's national biogas program supported the construction of 200,000 plants between 1992 and 2009 while Vietnam's national program promoted the construction of 26,000 plants between 2003 and 2006 (ter Heegde and Sonde, 2007; WHO, 2009). The Chinese government is seeking to increase the use of biogas plants from 15 million in 2004 to 27 million by 2010 and more recently, Cambodia and Bangladesh have also established national biogas programs.⁷ The Indian government has supported biogas since the 1970s and over 3.67 million plants were in operation in 2004 with around 1.1 million households currently using biogas as their main cooking fuel.

Given the recent increase in emphasis on (and funding available for) community based adaptation to climate change (IISD, 2010), the policy implications of biogas adoption as part of a broader decentralized energy strategy are significant in many parts of the global South; especially as in addition to providing clean energy from waste (with additional opportunities for improved sanitation), it avoids wider concerns about environmental sustainability, carbon neutrality and food versus fuel conflicts raised by many other biofuels (Abassi and Abassi, 2010). To maximise the environmental and health benefits

⁷ In Africa, however, the technology has been much less widespread (Heegde and Sonde, 2007).

associated with cleaner energy, however, there is a need for more comprehensive national energy policies in many parts of the global South that consider (human and physical) geographical variations in energy demand and supply options and the extent to which these can be combined with waste management/sanitation opportunities.

5. Conclusion

Despite the many inter-linkages between excreta, environmental quality and human health plus the fascinating ambiguities and variations over time and space in socio-cultural attitudes towards it, human waste rarely forms a central part of geographical analysis or academic research more generally (Black and Fawcett, 2008). Yet the interdisciplinary nature of our subject makes geographers ideally placed to investigate the socio-economic, cultural and environmental appropriateness of different excreta management systems and examine the cultural, economic and environmental variations associated with existing practices.

One of the main hindrances to the adoption of sewage management systems like ecosan and anaerobic digestion is the fact that wider taboos associated with human waste often render them culturally unacceptable (Black and Fawcett, 2008). In theoretical terms, this is fascinating as social conceptualisations of disgust vary enormously between different places and cultures and are rarely static. Given the willingness of geographers to engage in trans-disciplinary theoretical debates, there is scope to enhance understandings of how and why these conceptualisations vary over space and time and the influence that this has on the arrangement of different rural/urban and indoor/outdoor spaces.

With regard to human waste as a threat, the inherent spatiality of Douglas's (1966) work on pollution and taboo provides an important framework for theoretical analysis as demonstrated by Campkin and Cox's (2007a) work on geographies of dirt. In more practical terms, there is an urgent need to understand how local socio-cultural norms surrounding human excreta interact with wider political, physical and environmental constraints if appropriate and sustainable excreta management systems are to be developed for over 2.6 billion people.

Concepts like the 'pollution of poverty' (originating from the UN Conference on the Human Environment in Stockholm, 1972) and ideas of a 'retreat of poverty' into certain geographical areas provide good geographical perspectives for analysing wider political ecology debates about social and environmental justice (Rawls 1971; White, 1998; Shrader-Frechette, 2002; Hardoy et al, 2001; Bullard, 2005) and 'ecological distribution' (Martinez-Alier, 2002). Longstanding approaches such as welfare geography (Smith, 1973; Eyles, 1987) and territorial social justice (Harvey, 1972) are similarly well placed to investigate problems such as the unfair distribution of sanitation provision and excrement-related environmental/health burdens between socio-economic groups. Translating this knowledge into policy is not easy however due to the very private and locally specific nature of sanitation and hygiene practices (WHO, 2005) and the tendency for the 'great distaste' surrounding human excrement to hinder action on these issues (Black and Fawcett, 2008). Indeed, very few countries actually have explicit policies for

sanitation and hygiene promotion so the implementation of national and local sanitation policies often involves attempts to unite staff from the health, education, water and wider development fields.

The idea of human waste as a resource, meanwhile, lends itself to theoretical research on the extent to which cultural attitudes towards excrement are influenced by its perceived usefulness. It also offers opportunities for more policy-relevant research on potential interlinkages between alternative sanitation systems, excrement-fuelled biogas and 'humanure' in different socio-economic, cultural, political and geomorphological contexts. Again, though, translating such research into policy can be an uphill struggle given the low priority given to sanitation in much of the global South and a general lack of awareness among policy-makers about alternative sanitation systems such as ecosan. Nevertheless, there are signs that things are starting to change, and in May 2010, the Indian Ministry of Rural Development amended its Total Sanitation Campaign Guidelines to incorporate ecosan (Ecosanres, 2010). There are also a number of successful projects that illustrate how biogas sanitation can overcome initial socio-cultural resistance – even in faecophobic societies like India and Nepal (Sinha and Kazaglis, 2010; Lohri et al, 2010), but success is often greatest where the co-benefits of such systems (waste water treatment, sanitation, energy) are clearly demonstrated to potential users, funders and policy-makers.

In the global North, there are many isolated pockets of interest in ecosan and a range of technologies exist to produce humanure from dehydrating and composting toilets (Price, 2009), but few countries have an official policy encouraging alternative sanitation systems. Sweden is the obvious exception, demonstrating how ecosan can be promoted as part of wider sustainable development goals linked to eutrophication and the protection of freshwater and marine ecosystems (UNEP, 2010). But there are no technical barriers to other countries following Sweden's lead and participatory approaches can go a long way to understanding wider socio-economic and cultural obstacles. Indeed, applied geographical research has produced a wide range of environmental modelling and management tools that can integrate the views of local communities and have potential for use by local authorities that have responsibility for landuse, environmental planning and climate change adaptation (Wang et al, 2007; 2008; de Graaff, 2008; Maconachie; 2008; Zeilhofer and Topanotti; 2008; Dewan and Yamaguchi, 2009; Palm et al, 2009; Velázquez et al, 2009; Yadav et al, 2009; Mishra and Griffin, 2010).

By helping to enhance spatially-specific understandings of such complex socio-economic, cultural and environmental issues like sanitation, household energy preferences and the use of humanure with the use of participatory research approaches, this type of applied research would also help to respond to calls for more relevant and morally aware research within geography that engages with issues of inequality (Cloke 2002; Pain 2004). In 2008, Stephen Turner, then Policy Director of WaterAid, argued that in order to address the global problem of inadequate sanitation "*we need to put the word shit into people's mouths*" (quoted in *Sanitation Now* 2008, p. 2). Perhaps geographers could do something more than just talking about it?

Acknowledgements.

I would like to thank Emma Mawdsley and the editors/reviewers of *Applied Geography* for reading and commenting on earlier versions of this paper and also granny for entertaining Holly and Jude while the writing took place.

References

- Abbasi, T. and Abbasi, S.A. (2010). Biomass energy and the environmental impacts associated with its production and utilization. *Renewable and Sustainable Energy Reviews* 14, 919–937
- Abrahams, P. W. (2006). Soil, geography and human disease: a critical review of the importance of medical cartography. *Progress in Physical Geography* 30 (4), 490-512.
- Anayah, F. M. and Almasri, M.N. (2009). Trends and occurrences of nitrate in the groundwater of the West Bank, Palestine. *Applied Geography* 29 (4), 588-601
- Anderson, G. W. (1947). A German atlas of epidemic diseases. *Geographical Review* 37, 307-11.
- Appadurai. A. (2002). A deep democracy. *Public Culture* 14, 1
- Arby, G. (2008) Killing fields. The shame approach hobbles the big killer– open defecation. *Sanitation Now* 2008, 3.
- Andersson, I. (2001). Gender perspectives on ecological sanitation Paper presented at the Association of American Geographers' conference, New York, NY.
(<http://www.energyandenvironment.undp.org/undp/index.cfm?module=Library&page=Document&DocumentID=5262>) Accessed 15 August 2008
- Bacon, H. P. (1956). Human waste and soil productivity. *Journal of Geography* 55, 291-98
- Baker, K., & Jewitt, S. (2007). Evaluating thirty-five years of green revolution technology in villages of Bulandshahr District, western Uttar Pradesh, north India. *Journal of Development Studies*, 43, 312-339, (2).
- Balfour, E. (1946) *The Living Soil*. Faber and Faber, London.
- Bruce, N. Perez-Padilla, R. and Albalak, R. (2000). Indoor air pollution in developing countries: a major environmental and public health challenge. *Bulletin of the World Health Organization* 78 (9), 1078-1092
- Campkin, B. and Cox, R. (2007) (Eds.). *Dirt: New Geographies of Cleanliness and Contamination*. I B Tauris, London

- Cliff, A. D. Haggett, P. Smallman-Raynor, M. R. (2004) *World Atlas of Epidemic Diseases*. Arnold, London
- Cliff, A. D. Haggett, P. Smallman-Raynor, M. R. Stroup, D. F. and Thacker, S. B. (2008). *Infectious Diseases: Emergence and Re-emergence. A Geographical Analysis*. Oxford University Press, Oxford
- Cloke, P. (2002). Deliver us from evil? Prospects for living ethically and acting politically in human geography. *Progress in Human Geography* 26, 587-604
- Cohen, W. (2005). Introduction: Locating filth. In: Cohen, W. A. and Johnson, R. (Eds.) *Filth: Dirt, Disgust and Modern Life*. University of Minnesota Press, Minneapolis
- Collins, A.L. and Anthony, S.G. (2008). Predicting sediment inputs to aquatic ecosystems across England and Wales under current environmental conditions. *Applied Geography* 28 (4), 281-294.
- Collins, T.W. Grineski, S.E. and de Lourdes Romo Aguilar, M. (2009). Vulnerability to environmental hazards in the Ciudad Juárez (Mexico)–El Paso (USA) metropolis: A model for spatial risk assessment in transnational context. *Applied Geography* 29 (3), 448-461.
- Colten, C. E. (1994). Chicago's waste lands: refuse disposal and urban growth 1940-1990. *Journal of Historical Geography* 19, 433-37
- Cox, R. (2007). Introduction [to Section 3]. In Campkin, B. and Cox, R. (2007) (Eds.). *Dirt: New Geographies of Cleanliness and Contamination*. I B Tauris, London, pp. 153-55
- Cresswell, T. (1996). *In Place/out of Place: Geography, Ideology and Transgression*. University of Minnesota Press, Minneapolis
- Cresswell, T. (1997). Weeds, plagues, and bodily secretions: a geographical interpretation of metaphors of displacement. *Annals of the Association of American Geographers* 87 (2), 330-345
- de Graaff, J. Amsalu, A. Bodnar, F. Kessler, A. Poshumus, H. and Tenge, A. (2008). Factors influencing adoption and continued use of long-term soil and water conservation measures in five developing countries. *Applied Geography* 28 (4) 271-280.
- Defra (2009a). Anaerobic Digestion. <http://www.defra.gov.uk/farm/environment/climate-change/anaerobic-workshop/0907.htm>) Accessed March 02 2009.
- Defra (2009b) Farm Waste. (<http://www.defra.gov.uk/farm/waste/sludge/index.htm>). Accessed March 02 2009

Defra (2010) Anaerobic digestion.

(<http://www.biogas-info.co.uk/index.php/local-government>) Accessed 30 July 2010

Dewan, A. M. and Yamaguchi, Y. (2009). Land use and land cover change in Greater Dhaka, Bangladesh: Using remote sensing to promote sustainable urbanization. *Applied Geography* 29 (3), 390-401

Desai, V. (1995a). NGOs, gender mainstreaming, and urban poor communities in Mumbai, *Gender and Development* 13, 90-98

Desai, V. (1995b). *Community Participation and Slum Housing: A Study of Bombay*. Sage Publications, New Delhi

Douglas. M. (1966). *Purity and Danger: An Analysis of Concepts of Pollution and Taboo*. Routledge and Kegan Paul, London. First published 1966, reprinted 2002.

Duncker, L. C., Matsebe, G. N. and Moilwa, N, (2007). The social/cultural acceptability of using human excreta (faeces and urine) for food production in rural settlements in South Africa, Report to the Water Research Commission. CSIR Built Environment Unit Pretoria. WRC Report No TT 310/07.

Dutta, S., Rehman, I.H., Malhotra, P. and Venkata Ramana, P. (1997). *Biogas. The Indian NGO experience*. New Delhi: Tata Energy Research Institute.

Ecosanres, (2010) (<http://www.ecosanres.org/index.htm>) Accessed 30 July 2010.

Environmental Data Interactive Exchange, (2002). Germany Boasts Biogas from New Sewage Treatment Plant 06/09/2002, EDIE Newsroom, (http://www.edie.net/news/news_story.asp?id=5936) Accessed 15 August 2008

Esrey, S. A. Andersson, I. Hilliers, A. and Sawyer, R (2001). *Closing the Loop: Ecological Sanitation for Food Security*. UNDP and SIDA, Mexico (<http://www.undp.org/water/initiatives/ecol.html>) Accessed 15 August 2008

Esrey, S. A. Gough, J. Rapapor, D. Sawyer, R. Simpson-Hebert, M. Vargas, J. and Winblad, U. (1998). *Ecological Sanitation*. Swedish International Development Cooperation Agency, Stockholm

Energy Saving Trust, (2008). Biogas (<http://www.energysavingtrust.org.uk/fleet/technology/alternativefuels/biogas/>) Accessed 15 August 2008

EREC, (2009). RENEWABLE ENERGY POLICY REVIEW . Sweden. (www.erec.org/fileadmin/erec.../SWEDEN_RES_Policy_Review_Final.pdf Support for Biofuels). Accessed 30 July 2010.

Eyles, J. (1987). *The Geography of the National Health: An Essay in Welfare Geography*. Croom Helm, London

Gandy, M. (2005). The bacteriological city and its discontents. *Historical Geography* 34, 14-25.

Gandy, M. (2008). Landscapes of disaster. Water, modernity, and urban fragmentation in Mumbai. *Environment and Planning A* 40, 108-130.

Gasworld, (2010). Chesterfield BioGas to supply UK's first biogas upgrade plant to Centrica. (<http://www.gasworld.com/news.php?a=4929>) Accessed 30 July 2010.

George, R. (2008) The year London's stink returned. *Sanitation Now* 2008, 8.

Giles, H. and Brown, B. (1997). Water and sanitation services to the urban poor in the developing world. *Geography* 82, 97-109.

Goddard, N. (1996). 'A mine of wealth'? The Victorians and the agricultural value of sewage. *Journal of Historical Geography* 22, 274-290

Government of India, (2010). National Policy on Biofuels. Ministry of New & Renewable Energy, New Delhi.

Government of India, (2009). Launching of the 'National Biomass Cookstove Initiative' on 2nd December 2009 at New Delhi. Press Release. A New Initiative on Improved Biomass Cookstoves. Ministry of New and Renewable Energy. New Delhi.

Gregory, M. and James, S. (2006), *Toilets of the World*, London: Merrell.

Gregson, N. (2003) Reclaiming 'the social' in social and cultural geography. In: Anderson, K. Domosh, M. Pile, S. and Thrift, N. (Eds.). *Handbook of Cultural Geography*. Sage, London pp. 43-57

GTZ, (2010). Biogas sanitation for blackwater, brown water, or for excreta treatment and reuse in developing countries. Draft. (unapcaem.org/.../BIOGAS%20and%20DEWATS,%20a%20perfect%20match.pdf). Accessed 30 July 2010.

Guardian (2008). Digesting the problem. ([http://www.guardian.co.uk/environment/2008/jul/30/biofuels.waste?gusrc=rss&feed=environmentDigesting the problem](http://www.guardian.co.uk/environment/2008/jul/30/biofuels.waste?gusrc=rss&feed=environmentDigesting%20the%20problem)). Accessed 7 July 2009.

Haggett, P. (1994). Geographical aspects on the emergence of infectious diseases. *Geografiska Annaler* 76B, 91-104.

- Hannon, S. and Andersson, I. (2001). Gender perspectives on water supply and sanitation: Towards a sustainable livelihoods and ecosystem-based approach to sanitation. Paper presented at the Association of American Geographers' conference, New York, NY.
<http://www.energyandenvironment.undp.org/undp/index.cfm?module=Library&page=Document&DocumentID=5261> (accessed 16 July 2008).
- Harvey, D. (1972) Social justice and spatial systems. *Antipode Monographs in Social Geography* 1, 87-106.
- Haviland, A. (1982). *The Geographical Distribution of Disease in Great Britain*. Sonnenschein, London
- Hawkins, G. (2006). *The Ethics of Waste. How We Relate to Rubbish*. Rowman and Littlefield, Oxford
- He, C. Okada, N. Zhang, Q., Shi, P. and Zhang, J. (2006). Modeling urban expansion scenarios by coupling cellular automata model and system dynamic model in Beijing, China. *Applied Geography* 26 (3-4), 232-345.
- Holloway, L. Venn, L. Cox, R. Kneafsey, M. Dowler, E. and Toumained, H. (2007). Dirty vegetables: connecting consumers to the growing of their food. In Campkin, B. and Cox, R. (2007) (Eds.). *Dirt: New Geographies of Cleanliness and Contamination*. I B Tauris, London, pp. 178-188.
- Howard, A. and Wad, Y.D. (1931). *The Waste Products of Agriculture: Their Utilisation as Humus*. OUP, Oxford.
- Howard, A. (1940). *An Agricultural Testament*. OUP, Oxford.
- Howe, G. M. (1963). *National Atlas of Disease Mortality in the United Kingdom*. Nelson, London.
- Howe, G. M. (1980). Medical geography. In: Brown E H (Ed.). *Geography Yesterday and Tomorrow*. Oxford University Press, Oxford pp. 280-91
- IISD, (2010). A Summary of the Fourth International Conference on Community-Based Adaptation to Climate Change. *Community-Based Adaptation to Climate Change Bulletin* 135, (3) 2nd March (<HTTP://WWW.IISD.CA/YMB/CLIMATE/CBA4/>) Accessed 30 July 2010.
- Ivey, J.L. de Loe, R.C. and Kreutzwiser, R. D. (2006). Planning for source water protection in Ontario. *Applied Geography* 26 (3-4), 192-209
- Jewitt, S., & Baker, K. (2006). The Green Revolution re-assessed: insider perspectives on agrarian change in Bulandshahr District, Western Uttar Pradesh, India. *Geoforum*, 38(1), 73-89.

- Jewitt, S., & Labhsetwar, N. (2009). Gender, gobar and household energy. Exploring competition over a valuable resource in rural Uttar Pradesh. Paper presented at the UK-India Sustainable Energy Technologies Network, UK Workshop. Nottingham: Trent Bridge. 9-10th September 2009.
- Kamusoko, C. Aniya, M. Adi, B. and Manjoro, M. (2009). Rural sustainability under threat in Zimbabwe – Simulation of future land use/cover changes in the Bindura district based on the Markov-cellular automata model. *Applied Geography* 29 (3), 435-447
- Kay, D. Aitken, M. Crowther, J. Dickson, I. Edwards, A. C. Francis, C. Hopkins, M. Jeffery, W. Kay, C. McDonald, A. T. McDonald, D. Stapleton, C. M. Watkins, J. Wilkinson, J. and Wyer, M. D. (2007). Reducing fluxes of faecal indicator compliance parameters to bathing waters from diffuse agricultural sources: the Brighthouse Bay study, *Scotland Environmental Pollution* 147 (1), 138-49
- Kearns, G. (1984). Cholera and public health reform in nineteenth-century England and Wales: interpreting the geographical patterns. *Society for the Social History of Medicine Bulletin* 35, 30-2
- Kearns, G. (1989). Death in the time of cholera. *Journal of Historical Geography* 15 (4), 425-432
- Kearns, G. (1991). Cholera, nuisances and environmental management in Islington 1830-55. *Medical History Supplement* 11, 94–125
- Kearns, G. (2000). Town hall and Whitehall: Sanitary intelligence and the relations between central and local government, the case of Liverpool, 1840-63. In: Sheard, S. and Power, H. (Eds.) *The body and the City: Histories of Urban Public Health*. Avebury, Leicester 89-108
- Kitchin, R. M. and Hubbard, P. J. (1999). Editorial: research, action and ‘critical’ geographies. *Area* 31, 195-98
- Krantz, H. (2006). Household routines - a time-space issue: A theoretical approach applied on the case of water and sanitation. *Applied Geography* 26, 227-241.
- Kristeva, J. (1982). *Powers of Horror. An Essay on Abjection* (translated by Roudiez L) Columbia University Press, New York
- Laporte, D. (2000). *History of Shit*. (translated by Benabid N and El-Khoury R) MIT Press, Cambridge MA
- Lohri, C. Vögeli, Y. Oppliger, A. Mardini, E, Giusti, A. and Zurbrügg, C. (2010). Evaluation of Biogas Sanitation Systems in Nepalese Prisons. *IWA-DEWATS Conference 2010, Decentralized Wastewater Treatment Solutions in Developing Countries Conference and Exhibition, Surabaya, Indonesia; 23-26 March 2010*.

(www.eawag.ch/organisation/abteilungen/sandec/.../biogas_icrc_jails.pdf). Accessed 30 July 2010.

Maantay, J. and Maroko, A. (2009). Mapping urban risk: Flood hazards, race, & environmental justice in New York. *Applied Geography* 29 (1), 111-124.

Maconachie, R. Dixon, A.B. and Wood, A. (2008). Decentralization and local institutional arrangements for wetland management in Ethiopia and Sierra Leone. *Applied Geography* 29 (2) 269-279

Mae-Wan, H. (2008). Biogas bonanza for Third World development. Institute of Science in Society (<http://www.i-sis.org.uk/BiogasBonanza.php>) Accessed 20 January 2008

Martinez-Alier, J. (2002). The environmentalism of the poor. Paper presented for the conference on 'The political Economy of Sustainable Development: Environmental Conflict, Participation and Movements. Friday 30 August, 2002. University of Witwatersrand, Johannesburg.

Matless, D. (2001). Bodies made of grass made of earth made of bodies: organicism, diet and national health in mid-twentieth century England. *Journal of Historical Geography* 27 (3), 355-376

May, J. M. (1950). Medical geography. Its methods and objectives. *Geographical Review* 40 9-41

May, J. M. (1952). Map of the world distribution of hemminthiasis. *Geographical Review* 42, 98-101

McFarlane, C. (2008a). Governing the contaminated city: infrastructure and sanitation in colonial and post-colonial Bombay. *International Journal of Urban and Regional Research* 32 (2), 415-435.

McFarlane, C. (2008b). Sanitation in Mumbai's informal settlements: state, 'slum', and infrastructure. *Environment and Planning A* 40, 88-107.

Miller, W. I. (1997). *The Anatomy of Disgust*. Harvard University Press, Cambridge MA

Mishra, S. R. and Griffin, A. L. (2010). Encroachment: A threat to resource sustainability in Chilika Lake, India. *Applied Geography* 30, 448-45

O'Hara, S. L. Hannan, T. and Genina, M. (2007). Assessing access to safe water and monitoring progress on MDG7 Target 10 (access to safe water and basic sanitation): Lessons from Kazakhstan, *Water Policy* 10 (1), 1-24

- Palm, M. Ostwald, M. Berndes, G. and Ravindranath, N.H. (2009). Application of Clean Development Mechanism to forest plantation projects and rural development in India. *Applied Geography* 29 (1), 2-11.
- Pain, R. (2003). Social geography: on action-oriented research. *Progress in Human Geography* 27, 677-685
- Pain, R. (2004). Social geography: participatory research. *Progress in Human Geography* 28 (6), 652-663
- Picton, L.J. (1946). *Thoughts on Feeding*. Faber and Faber, London.
- Poovey, M. (1996). *Making a Social Body*. University of Chicago Press, Chicago.
- Price, C. (2009) Humanure: the end of sewage as we know it? (<http://www.guardian.co.uk/environment/2009/may/12/humanure-composting-toilets>) Accessed 30 July 2010.
- Rahman, A. (2008). A GIS based DRASTIC model for assessing groundwater vulnerability in shallow aquifer in Aligarh, India. *Applied Geography* 28 (1), 32-53.
- Reddy, A. K. N. Rajapapaian, P. and Somasekhar, H.I. (1995). Community biogas plants supply energy and water. The Pura village case study. In: Goldemberg, J. and Johansson, T. B. (Eds.). *Energy as an Instrument for Socio-economic Development*. New York: United Nations Development Program. 80-88.
- Reeves, A. D. and Patton, D. (2005). Faecal sterols as indicators of sewage contamination in estuarine sediments of the Tay Estuary, Scotland: An extended baseline survey. *Hydrology and Earth System Sciences* 9, 81-94.
- Rhoades, E.L., O'Neal, M. A. and Pizzuto, J. E. (2009). Quantifying bank erosion on the South River from 1937 to 2005, and its importance in assessing Hg contamination. *Applied Geography* 29 (1), 125-134.
- Rockefeller, A. (1998). Civilization and sludge: notes on the history of the management of human excreta. *Capitalism Nature Socialism* 9 (3), 3-18.
- Rodriguez, L. and Preston, T. R. (2007) Biodigester Installation Manual. (http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGA/AGAP/FRG/Recycle/bio_digester) Accessed 12 August 2008
- Rosemarin, A. (2008). Small systems best for many cities. *Sanitation Now* 2008, 12
- Rupke, N. N. (Ed.). (2000). Medical Geography in Historical Perspective. Medical Geography Supplement 20 Wellcome Trust Centre for the History of Medicine at UCL, London

Satterthwaite, D. (2003). The Millennium Development Goals and urban poverty reduction: great expectations and nonsense statistics. *Environment and Urbanization* 15, 179-190.

Shailaja, R. (2000). Women, energy and sustainable development. *Energy for Sustainable Development*. 4 (1) 45-64.

Sheail, J. (1993). Sewering the English suburbs: an interwar perspective. *Journal of Historical Geography* 19, 433-37

Sibley, D. (1995). *Geographies of Exclusion: Society and Difference in the West*. Routledge, London

Sinha, S. and Kazaglis, A. (2010). Biogas and Dewats: A perfect match? (unapcaem.org/.../BIOGAS%20and%20DEWATS,%20a%20perfect%20match.pdf). Accessed 30 July 2010.

Smallman-Raynor, M. R. and Cliff, A. D. (2001). Epidemic diffusion processes in a system of U.S. military camps: transfer diffusion and the spread of Thyphoid Fever in the Spanish-American War, 1898. *Annals of the Association of American Geographers* 91(1), 71-91

Smallman-Raynor, M. R. and Cliff, A. D. (2004). The geographical spread of Cholera in the Crimean war: epidemic transmission in the camp systems of the British Army of the East, 1854-5. *Journal of Historical Geography* 30, 32-69

Smallman-Raynor, M. R. and Cliff, A. D. Trevelyan, B. Nettleton, C. and Sneddon, S. (2006). *Poliomyelitis. A World Geography: Emergence to Eradication*. University Press, Oxford

Smith, D. M. (1973). *The Geography of Social Well-being in the US*. McGraw Hill, New York.

Santerre, M. and Smith, K. (1982) 'Measures of appropriateness: the resource requirements of anaerobic digestion (biogas) systems' *World Development* 10, (3) 239-261.

Smith, P. J. (1975). The foul burns of Edinburgh: Public health attitudes and environmental change. *Scottish Geographical Magazine* 91, 25-37.

Swyngedouw, E. Kaiko, M. and Castro, E. (2002). Water: a political ecology perspective. *Built Environment* 28, 124-37.

Swyngedouw, E. (2004). *Social Power and the Urbanization of Water: Flows of Power*. Oxford: Oxford University Press.

Taglia, P.J., (2010). Emerging Policy Opportunities for the Biogas sector. 5th Agstar National Conference, April 28, 2010.
(www.epa.gov/agstar/pdf/conf10/TagliaBiogasAgSTAR.pdf). Accessed 30 July 2010.

ter Heegde, F. and Sonde, K., (2007). Biogas for a better life. An African Initiative. Domestic biogas in Africa; a first assessment of the potential and need
(www.mewd.gov.zm/index2.php?option=com_docman) Accessed 2nd August 2010.

Thames Water, (2009). Poo power cuts Thames electricity bill by £15m
(<http://www.thameswater.co.uk/cps/rde/xchg/corp/hs.xsl/9849.htm>.) Accessed 7 December 2009.

UNEP (2008). Ecological Sanitation (<http://www.undp.org/water/initiatives/ecol.html>)
Accessed 12 July 2008

UNEP, (2010). Innovative practices to enhance implementation of WSSD targets. Swedish initiative for ecological sanitation
(www.unep.org/GC/GCSS-VIII/Sweden_sanitation.pdf) Accessed 30 July 2010.

Velázquez, A. Cué-Bár E.M. Larrazábal, A. Sosa, N.-Villaseñor J.L. McCall, M. and Ibarra-Manríquez, G. (2009). Building participatory landscape-based conservation alternatives: A case study of Michoacán, Mexico. *Applied Geography* 29 (4) 513-526

Venkataraman, C. Sagar, A.D. Habib, G. Lam, N. and Smith, K.R. (2010). The Indian National Initiative for Advanced Biomass Cookstoves: The benefits of clean combustion. *Energy for Sustainable Development* 14, 63–72

Wang, X. Yu, Z. Cinderby, S. and Forrester, J. (2007). Enhancing participation: Experiences of participatory geographic information systems in Shanxi province, China. *Applied Geography* 28 (2) 96-109

Watson, R. T. and Zakri, A. H. (2008). Living Beyond Our Means. Natural Assets and Human Well-being. Statement from the Board. Millennium ecosystem assessment
(<http://www.millenniumassessment.org/documents/document.429.aspx.pdf>) Accessed 12 August 2008

Welsh School of Architecture, (2008). Case study: the Bromma biogas plant, Stockholm,
(<http://www.cardiff.ac.uk/archi/programmes/cost8/case/watersewerage/bromma.html>)
Accessed 12 August 2008.

Wherever the Need, (2008). (www.wheretheend.org.uk) Accessed 12 August 2008

WHO, (2005). Sanitation and Hygiene Promotion. Programming Guidance.
(www.who.int/entity/water_sanitation_health/hygiene/sanhygpromo.pdf) Accessed 30 July 2010.

WHO, (2006). Poverty-Environment Partnership. (www.who.int/entity/water_sanitation_health/hygiene/sanhygpromo.pdf) Accessed 30 July 2010.

WHO, (2009). Regional Workshop on Ecological Sanitation. Kathmandu, September 2008 (www.searo.who.int/LinkFiles/SDE_EH-557.pdf) Accessed 30 July 2010.

Yadav, Y., Malanson, G.P. Bekele, E. and Lant, C. (2009). Modeling watershed-scale sequestration of soil organic carbon for carbon credit programs. *Applied Geography*, 29, (4), 488-500

Zeilhofer, P. and Topanotti, V. P. (2008). GIS and ordination techniques for evaluation of environmental impacts in informal settlements: A case study from Cuiabá, central Brazil. *Applied Geography* 28 (1), 1-15.