Microbes, chemicals and the health of homes: integrating theories to account for more-than-human entanglements

Abstract

In the post-war period the health risks posed by indoor environments have both transformed and challenged notions of environmental health centred on pathogenic germs. The composition of home spaces, particularly in developed nations, has been fundamentally altered by the introduction of formerly industrial chemicals to everyday products and building materials. Further, the changing nature of building design, cleaning practices and urban life have altered the 'microbiomes' of homes, contributing to a rise in certain immune system conditions. This paper contends that to begin to address these concerns, the microscopic elements of 'indoor ecosystems', and how they are created and maintained, must become a focal point for research. It proposes an approach that integrates social practice theories and multispecies ethnography to investigate the cumulative constitution of indoor spaces. Findings detail the application of this approach to research into the domestic hygiene practices of parents with young children in Sydney, Australia. This approach highlights crucial assumptions about the ways micro-scale agency is embedded in everyday domestic practices that are contributing to sub-optimal indoor environments.

Keywords: Multispecies ethnography, Social Practice Theory, Indoor environmental health, micro-species

Introduction

Homes are intended to be safe spaces that protect the body from external sources of harm. It is widely accepted that safety and comfort are denied when people do not possess the means to build adequate shelter or cannot occupy homes on land that is safe from pollution, extreme environmental conditions or political upheaval. However, the maladaptive environmental conditions that characterise many homes in modern industrialised countries are more subtle, insidious and often physically and politically invisible. The new classes of post-industrial chemicals that afford modern homes and lifestyles many of their crucial aesthetic and functional qualities are interfering in bodily and environmental processes in unprecedented

ways (GSPI, 2016, Lakind and Birnbaum, 2010, Kessler, 2015). Chemical contamination is no longer exclusively an issue of the poor and marginalised, but an integral and often *essential* part of the materials that characterise lifestyles to which wealthy and middle classes aspire. Moreover, the types of microbial communities that are mutually supportive of human health and development are increasingly absent under modern, urban 'hygiene regimes'; contributing to a rise in health conditions such as allergies (Maizels, 2005, Rook, 2012). As the middle class grows across many developing and industrialised countries, the materials and practices that accompany definitions of prosperity, success and the domestic 'good life' must become a point of greater critical reflection.

The hygiene regime that has developed and proliferated in the context of this research, in Sydney, Australia, has followed a similar trajectory to its colonial counterparts in the Global North, to which the dominant state institutions and culture looked for structural and moral guidance. Invariably, the manifestations and evolution of hygiene practices and institutions in Australia developed with their own flavour, emerging in response to (although not necessarily well adapted to) it geographical peculiarities. As in Europe and North America the lineage of hygiene practices in Australia is owed to a Victorian culture which made 'cleanliness' into a civic responsibility and duty. However, Bashford (2003: 3) argues that hygiene has been particularly central to modern identity formation Australia:

> The pursuit (at many levels) of health, hygiene and cleanliness was one significant way in which the 'whiteness' of white Australia was imagined, as well as technically, legally and scientifically implemented.

Aside from the moral imperatives and anxieties associated with colonisation, particular events, such as the 1880s smallpox epidemic, shaped and solidified hygiene bureaucracy in Australia and its associated measures to prevent pathogens from spreading (Bashford, 2003). During this time, Davison (2008: 42) notes that "English visitors hailed the apparent superiority of Australian bathing arrangements". Although variously diluted and altered, the fundamental tenants of the 'hygiene regime', comprised of institutions, practices and beliefs about disease, instituted in this period persists today (Bashford, 2003).

Similarly, the post-war chemical boom infiltrated the domestic environment, and its throng of new modern products with a gusto that paralleled other wealthy, industrialised nations (Benn,

2004). The benefits of these developments remain out of reach for many Australians, particularly the first Australians living in remote communities, often without access to basic services, but who will nonetheless experience the effects of the ecological alterations wrought by the last century (or more) of hygienic and chemical 'improvements'(Lea and Pholeros, 2010). Although the emerging indoor health risks discussed in this paper are affecting bodies irrespective of social status, the inequitable distribution of benefit and harm adds additional urgency to addressing the drivers of maladaptive indoor ecologies.

The emerging concern for health risks associated with low microbial diversity and post-industrial chemicals are part of, and made legible by, a rise in technoscientific practices and modes of thinking that have increasingly focused on health in a molecular register. Rose (2007) has theorised how the 'molecularisation' of life is part of a new politics of life within biomedicine, which has not only refocused our understanding of what life is, and the risks posed to it, but what it means to be a good citizen. Rose and Novas (2005) employ the term biological citizens to refer to the ways individuals use biological knowledge to both comprehend their bodies, and to conform to the norm of a healthy citizen. The current context in which biological citizenry is defined is tied up with what Paxson has termed 'microbiopolitics' "the recognition and management, governmental and grassroots, of human encounters with the vital organismic agencies of bacteria, viruses, and fungi" (Paxson, 2008, p. 23). This concept links Foucault's notion of biopolitics - how governments seek to manage the health of populations by determining what types of life are allowed to thrive - and Latour's (1988) account of 'Pasteurian' hygiene, as the dominant way in which microbial entities have been made sensible in order to be controlled. From this, she argues, emerged a 'germophophic' hygiene regime which became normalised in the Victorian period and remains embedded in the definitions and measurements of hygiene operationalised through scientific instrumentation, institutions, urban infrastructures and individual practices.

Murphy (2008) suggests that these theorisations of the molecularisation of life could be usefully extended to make sense of the toxic exposures that accompany the proliferation of post-industrial chemicals. She proposes the concept of a 'chemical regime of living', characterised by new forms of molecular relations and risk that must be conceptualised at a global scale. New instruments for scientific measurement at the molecular level have enabled these molecular exchanges to become sensible and traceable in different landscapes across scales. However, unlike the 'germs' that make themselves known through entrenched

institutions, infrastructures and practices, post-industrial chemicals have been often deliberately excluded from narratives of harm and responsibility (Murphy, 2008). That is, the harm created by toxicants has been purposefully designated as outside of the responsibility of the industries that produce and regulate them, creating what Murphy (2006) calls a 'regime of imperceptibility' around synthetic molecular relations.

There are research programs and literature beginning to recognise and address aspects of these issues at the micro-scale of indoor ecologies. This research not only details the unique ecological niches developing for different microbes through the emergence of new materials and architectural forms in homes around the world (see Dunn et al., 2013, Green, 2014), or how chemical compounds in indoor air interact and transform throughout a normal day (see The Chemistry of Indoor Environments Program: https://indoorchem.org/) but is beginning to challenge 'germophobic' conceptions of microbial relations. Collaborations between microbiologists, social scientists and citizens in projects such as the UK based *Good Germs, Bad Germs* have investigated and challenged normative hygiene practices in peoples' homes (Greenhough et al., 2018). This type of challenge is also occurring at broader ecological scales, through investigations of the relationship between urban ecologies, microbial biodiversity and human health (Mills et al., 2017). These projects can be considered as part of what Paxson (2008) has termed a 'post-Pasteurian' turn, in which hygiene regimes oriented to germ-extermination are being contested in certain spaces and activities (Spackman, 2018, Lorimer, 2017). However, the ways in which 'post-Pasteurian' relations with microbial communities are infiltrating institutions and everyday practices to challenge dominant hygiene regimes, and how they intersect with other practices that influence indoor ecologies, such as chemical use, remains largely unknown.

Similarly, there is a growing number of collaborations between environmental sociologists, chemists and citizens in the tradition of 'popular epidemiology' (Brown, 1997) that monitor how exposures to household chemicals affect home occupants. Well known examples such as the Household Exposure Study, a North American project that evaluated exposures to pollutants from legacy contaminants, consumer products, and local emissions (Brody et al., 2009) and studies into the health impacts of fragranced products in Australian homes (Steinemann, 2015) and many others (see Loretz et al., 2008, Wilson et al., 2003, Morawska et al., 2018, Weatherly et al., 2017) are making visible, and political, previously obscured molecular interactions. Given that harm must be demonstrated in a molecular register to be

recognised by chemical regulators, these sensing and biomonitoring activities have provided one of the few ways that molecular relations can be made legible and political. However, concerns have been raised that by participating in evidence creation at the molecular scale, there is a risk of reproducing a conceptualisation of harm that requires individual offending chemicals to be identified, traced and linked directly to the manifestation of harm in an individual (Murphy, 2008). This type of measurement cannot capture the scope of contingent, complex ways in which both post-industrial chemicals and microorganisms interact and move through bodies and landscapes to cause harm.

This paper proposes another potential avenue for making indoor chemical and microbial relations knowable beyond isolated interactions at the molecular level, by focusing on how common, normative domestic practices performed by individuals structure material flows within homes. In doing this, we do not further situate blame or responsibility for creating problematic conditions or changing them with individuals. Rather, a focus on collective practices - as enactments of both a 'hygiene regime' and a 'chemical regime of living' – can reorient attention away from the individual to examine the intersection of macro-political and macro-infrastructural factors, with the micro-political and micro-material interactions that comprise everyday life. A practice-oriented inquiry is not intended as an alternative to approaches such as citizen sensing or biomonitoring, that make micro-entities perceptible at the molecular scale, but as another route of insight that could situate this data in the everyday relations that generate it.

This paper divided into two parts. The first half develops a theoretical lens that integrates social practice with multispecies and chemo-ethnographic approaches to investigating practices that embody and reproduce regimes of hygiene and chemical living. The latter half then applies this framework to explore the socio-material processes that influence the composition of indoor spaces through an investigation of the domestic hygiene practices of parents with young children in Sydney, Australia.

Investigating more-than-human practices: a hybrid approach

We propose that the integration of theories of social practice with aspects of multispecies and chemo-ethnography may yield novel insights into the constitution of practices and the emergent agency of their invisible participants. Social practice theories offer a way of tracing

collectively held, repeated sequences of action, to investigate how they configure, and are configured by, the environments in which they take place. The proponents of this theoretical lens, although heterogeneous, are united by the premise that social practices constitute the basic unit of enquiry into social life (Hui et al., 2016). Social practices are commonly characterised as organised sets of linked actions repeatedly performed across time and space that connect, support and compete with one another to make up the observable socio-material world (Schatzki, 2016). These organised sets of linked actions involve interactions between 'elements', often conceived of as meanings (thoughts, beliefs, values), bodily competencies (corporeal skills and embodied knowledge), and materials (infrastructures, artefacts, bodies) (Shove et al., 2012, Cass and Faulconbridge, 2016, Ryghaug and Toftaker, 2014). Examples of practices include cooking, cleaning, and commuting, or the routinised work practices of builders, office workers, regulators and scientists, which although infinitely diverse, maintain common characterises in particular places and times that are shared by the members of a group that performs them. By setting the normative criteria that shapes notions of how everyday activities *should* be performed, practices generate not only the expectations and measurements through which ideas such as cooking and cleaning 'well' are maintained, but many of the assumed needs that these practices service.

We propose that a focus on practice enables an examination of how the ecologies of homes are cumulatively and interactively built through repeat performances of coordinated activities. Importantly, it also provides a way of recognising and interrogating the ways in which these configured indoor terrains produce effects beyond those intended on human, and more-than-human, ecologies. By attending to practices in the analysis of socio-material conditions, attention is reoriented not only to *what* materials people interact with, but to *how, when, why* and *how often*.

This paper specifically addresses the assumptions embedded within practices that generate expectations of what a healthy home should look and feel like, and how these practices may consequently be affecting indoor micro-ecologies. Collective lifestyle practices establish criteria for, and make sense of, what a kitchen is *for*, what wall paint should look like, or how many bathrooms a single family should have to meet expectations of cleanliness and comfort. An analytical focus on practices can bring into view the entities and interactions that reproduce existing conceptions of domestic health and hygiene, and the structures that are, in part, built to facilitate these perceived needs. From this perspective, social practices are seen

to embody and reinforce ‘regimes of imperceptibility’ in which infrastructural sources of toxicant exposure, and the need for home and urban design that fosters microbial diversity, have been excluded.

By advocating a focus on practices, we do not suggest that producers of toxicants and toxic infrastructures should not be addressed at a structural level, nor do we imply individuals enacting these practices should be held responsible for managing toxic exposures in the home. Indeed, this approach suggests the opposite. One of the central tenants of a social practice lens is the rejection of the individualisation of responsibility in favour of attending to the dynamic interplay between practices that evolve over time and are recurrently maintained at a broad societal level (Schatzki et al., 2001, Sahakian and Wilhite, 2014, Shove et al., 2012). For normative practices to persist, they must be collectively ‘carried’ by multiple members of a social group over time. It is at this scale they become relevant, and a useful analytical unit to begin thinking about how certain socio-material conditions evolve and what interventions may be effective. In the event that structural issues related to chemicals allowed in products, building materials, and the land that buildings can be built on, were politically rectified, the normative expectations of hygiene and cleanliness embedded in practices may still persist. These practices, and the definitions of hygiene physically and materially embedded within them, must consequently still be addressed.

Although the value of an orientation to practices is increasingly recognised across the social sciences, currently dominant ways of theorising materiality within social practices has attracted criticism (Maller, 2018, Hui et al., 2016). Social practice theories are currently being challenged with regard to their conceptualisations of non-human agency. Although practice theories decentre human agency in favour of a relational conceptualisation of agency that emerges through interactions between humans and non-humans, they generally maintain that practices are necessarily performed and ‘carried’ by humans (Maller 2018). This position is being problematised by findings, particularly in the life sciences, that microorganisms and chemicals display forms of relational and emergent agency within human bodies and the environment that significantly influence practices and broader ecological processes beyond human-led actions. As a result, scholars such as Nicolini (2016) and Thrift (2016) are increasingly drawing on other more-than-human approaches such as non-representational and assemblage-based thinking, to add additional nuance to investigations of the material element of practice. Compelling examples are provided by Maller (2016) and Fox et al (2017) who

argue that social practice theories are not sufficiently attentive to the materiality of bodies, and that while bodies are acknowledged, their physical and sensory qualities are largely "unrecognised or dematerialised" Maller (2016: 72). Maller consequently integrates concepts from epigenetics, geography and anthropology to add nuance to the role of affective and biophysical properties of bodies in social practices (Maller, 2018: 78).

In this paper we propose a theoretical lens that endeavours to expand the notion of materiality within social practice theories to account for the emergent agency of microbial communities and post-industrial chemicals, by drawing on ideas from multispecies and chemoethnography. Multispecies and chemoethnographers focus on the emergence of new social realities through dynamic interactions between other living species and chemicals, respectively. In recognising the dynamic effects produced through interactions between human practices, other living species, and chemical actors, we propose that a more adequate account of practice can be developed to aid in the investigation of complex more-than-human entanglements within indoor ecologies.

Multispecies ethnographers are interested in how political, economic and cultural forces shape the livelihoods of a multitude of organisms. As Kirksey and Helmrich (2010) state, multispecies ethnographers are studying the contact zones where lines separating nature from culture have broken down and where human and other species can be seen as mutually constituting their shared ecological habitats and one another. Haraway's insight in *When Species Meet* that "I am vastly outnumbered by my tiny companions… To be one is always to *become with* many" (2008: 4) is foundational to this 'species-turn' in anthropology, and the emerging understanding that humans are constituted by a multitude of species all of which exhibit specific forms of agency unique to the more-than-human entity of which they are part. Multispecies research into the mutually constitutive role of humans and the micro-organisms with which they co-habitate has enriched our understanding of, for example, what makes healthy soil in agro-ecosystems (Granjou and Phillips, 2018), and the role of social relations in the proliferation of bovine tuberculosis (Robinson, 2018).

Chemo-ethnography adopts a similar mode of attention to account for the ways that modern chemistry is producing new social, political and economic relations, which create possibilities for life, while also adversely affecting human health and landscapes (Shapiro and Kirksey, 2017). By following chemicals, and their reactions, emergence, and decay in more-than-

human worlds, anthropologists are starting to investigate how chemical agents are perpetuating certain social arrangements and transforming others (Landecker and Panofsky, 2013, Myers, 2015, Liboiron, 2015). Central to these approaches is the attention to material difference and relationality, and how these differences produce emergent forms of 'chemo-sociality'. Its central questions are thus "how are molecular frictions, catalytic dynamics, forms of not-Life, and other-than-life reconfiguring our conditions of knowing, being, and sociality?" (Shapiro and Kirksey, 2017). By attending to multi-species and chemical relations, multispecies and chemo-ethnographic approaches enable the living and non-living non-humans[1] that are creating present chemo-socialites in indoor environments to be articulated and followed.

Social practice and multispecies ethnographic[2] approaches share an interest in the materiality and ordering of daily life, a methodological commitment to ethnography, a decentralization of individual agency in favor of more emergent and relational conceptualizations, and a normative concern with the implications of practices, particularly in relation to environmental justice (Phillips, 2014). Following Maller (2018), we take social practices as a 'lead' theoretical framing to orient this investigation to tracing and accounting for the practices that continuously configure the material world. Multispecies approaches are integrated to interrogate how particular forms of human and non-human agency are influenced by, and emerge from, practice with a particular focus on micro-scale interactions. The synthesis of these ideas enables an examination of both emergent agency and forms of repetition which build indoor environments over time.

Theorising micro-species

We propose that in analysing the micro-ecological relations in homes it is useful to theorise chemical and microbial entities together. Following thinkers such as Abrahamsson et al. (2015) and Povinelli (2016), we resist a flattening of distinctions between these different forms of entities, or their designation as all similarly 'living'. Rather, we are interested in how their specific kinds of difference and dynamism result in the expression of particular

[1] It is acknowledged that the term 'non-human' is imperfect and grounded in human exceptionalism

[2] We will use the term multispecies approaches to refer to both multispecies and chemo-ethnographies from this point unless specified otherwise.

kinds of emergent entanglements that build and transform everyday domestic ecologies. To do this requires a different theorisation of matter to those that rely on certain kinds of living/non-living distinctions. We propose that a useful category for the purposes of this theorisation is 'micro-species'.

Species, a term now perhaps most commonly associated with biology, is defined in that field as "A group of living organisms consisting of similar individuals capable of exchanging genes or interbreeding. The species is the principal natural taxonomic unit, ranking below a genus…" (OED, 2019). However, it is also commonly used in physics and chemistry to refer to "a particular kind of atom, molecule, ion, or particle" (OED, 2019). At one point within biology it was considered that the taxonomic system to which species belongs was a way of detecting 'natural' or 'essential' kinds that pre-existed in nature, although this is no longer a prominent debate, traditional conceptions of species in biology maintain that species are relatively stable, fixed, autonomous units with set boundaries (Dupré, 1992). Conversely, it is commonly acknowledged that chemical species can shift and morph according to their environmental conditions and interactions. These different applications of the term species show how the conditions for denoting 'kinds or sorts' of entities are determined by the priorities of the classification system.

We propose that for our purposes, distinguishing the morphological scale of the 'micro' in relation to species is useful for two key reasons. First, as O'Malley and Dupré (2007) contend, the micro-scale of biology is offering some of the greatest challenges to species concepts that have traditionally dominated the philosophy of biology, as the evidence of practices, such as 'horizontal gene transfer', have shown that the boundaries between organisms appear to be comparatively more malleable than what has been traditionally observed in macro species. Transgressions of microbial boundaries are often the product of changed environmental conditions, meaning that microorganisms need to search for resources or new ways of performing different roles within a system (Darling et al., 2016). This boundary plasticity is also applicable to chemical species at the micro-scale. As noted above, chemical species can change from one categorically distinct entity to another according to environmental conditions (Shapiro and Kirksey, 2017). By employing the term 'species', we aim to highlight the limitations of operative concepts of species as single, autonomous, entities, and attempt to reimagine the term as a useful, expanded category for understanding distinction within a complex, interactive ecosystem.

The first reason we propose a joint theorisation of microorganisms and chemicals as micro-species is this environmentally contingent morphological capacity. Numerous scholars across the social and natural sciences have postulated about the extent to which humans are co-constituted by micro-organisms, and what this means for what humans, are and where the boundaries around our bodies as discreet entities can be drawn (Paxson and Helmreich, 2014, Hird, 2010, O'Malley and Dupré, 2007). Others, (see Liboiron, 2015, Murphy, 2008) have argued that other non-living micro-actors, such as post-industrial chemicals, also 'participate' in and alter the ways bodies function based on environmental variables, due to their unique properties. Within an ecosystem such as a body, or a bath, chemical and microbial species' boundaries can shift as they transform one another interactively based on material flows through that space over time, while retaining core characteristics afforded by the molecules from which they are made.

The second reason is that both chemicals and microbes exert agency in everyday practices dynamically between imagined and physical registers. The assumed or potential presence of 'germs' and chemical toxicants has considerable influence over everyday enactments of hygiene, even when no pathogens or toxicants are physically present (Jack, 2017, Smith, 2007). Where micro-species are physically present, they shape practices differentially according to how they are present, how much of them is present, how often, and how they can be removed. Whether or not micro-species become perceptible is therefore not always related to their actual existence in a location, but the presence of particular material and cultural conditions in which they emerge as sensable, become hidden, or are imagined to exist.

By following emergent manifestations of micro-species the researchers' attention is drawn to relational forms of agency at the micro-scale. We propose that understanding how micro-species boundaries shift in response to environmental conditions, and their continual transition between real and imagined entities, will be central to improving knowledge of how microbial and chemical agents collectively and repeatedly assemble indoor environments and their occupants.

In this initial theorisation of micro-species for the purposes of our research, micro-species include microbes[3] viruses, active organic and inorganic chemical species and other non- inert entities that demonstrate degrees of autonomous reactive action act at a micro-scale. Further applications of this category could be explored in future research engaging with different types of dynamic micro-entities.

In the following section we provide an overview of the ethnographic fieldwork to which this hybrid theoretical approach is applied, and the types of insights it affords into emergent micro-species agency in hygiene practices.

Integrating theories in practice

Addressing the multitude of interacting forces that can produce harm in home micro-ecologies will require large structural changes with inputs based on extensive cross-disciplinary and contextually sensitive research. To begin this journey, we suggest it is essential to start to investigate how particular socio-material arrangements are generated in the home through situated dynamic interactions between agents within and across practices

The research presented here focuses particularly on practices enacted by parents to create a safe, hygienic, home environment for their children. Greenhough et al. (2018) propose that domestic spaces, such as the kitchen, are key sites in which Pasteurian microbiopolitics are combined with the production of biological citizens. An examination of these sites can provide insight into the cultural reproduction of what is considered healthy and safe – and what it means to be a good citizen – and how these notions are and can be challenged. Although notions of hygiene are embedded across a multitude of practices, 'hygiene practices' are taken here to mean the practices performed wholly, or in part, to maintain health and prevent disease in an environment. These encompass practices such as cleaning a bathroom, aspects of meal preparation and personal care that are guided by normative conceptions of what cleanliness is and how it is supposed to be maintained. Although all practices influence the flow of materials and microorganisms through the home, research suggests that practices enacted to achieve a clean home, particularly via anti-microbial

[3] Microorganisms are generally divided into seven types: bacteria, archaea, protozoa, algae, fungi, viruses, and multicellular animal parasites. Each has a characteristic cellular composition, morphology, mode of reproduction and locomotion.

394 products, play an especially important role in adding or removing material entities that
395 contribute to health outcomes (Bloomfield et al., 2006, Jeon et al., 2013, Hartmann et al.,
396 2016).
397
398 With the intention of gaining insight into the role of domestic practices in reproducing
399 particular notions of hygienic living, we explored the routine hygiene practices of ten parents
400 with children under the age of five in Sydney, Australia during 2017.[4] Parents with children
401 under five were selected because research suggests these children are in critical "windows of
402 vulnerability" and are consequently more susceptible to the health risks associated with sub-
403 optimal indoor micro-ecologies, including auto-immune conditions and the multitude of
404 conditions associated with endocrine disrupting chemicals (Landrigan and Goldman, 2011,
405 Crain et al., 2008). Despite attempts to recruit broadly through community groups and
406 organisations throughout Sydney, and online, the group of individuals engaged was
407 comprised of well-educated, predominantly female (9/10), parents living in moderately
408 affluent to affluent areas of Sydney, in medium to large duplex or free-standing houses. All
409 participants, aside from one, spoke English as a first language. Although greater insights
410 could be achieved with a larger and more diverse sample, this research provides insights into
411 the practices of relatively well educated and economically advantaged parents in Sydney. It
412 also represents a set of lifestyle practices that emerging middle classes may adopt into the
413 future.
414
415 As with all investigations of practices, the findings presented here are deeply situated. A
416 similar investigation in another location, or with families from different cultural backgrounds,
417 would certainly reveal significant cultural and geographic variation. The international
418 standardisation of practices that conform to a 'germophobic' hygiene regime (Shove, 2003,
419 Jack, 2017, Quitzau and Røpke, 2009) and chemical regimes of living (Murphy, 2008) have
420 been consistently detailed, and are a product of global forces and structures. However, the
421 dynamics that shape these practices and their ecological outcomes are always contingent on
422 local particularities, distortions, rejections and reappropriations. This investigation is not

[4] Given the depth of engagement with each participant and the purpose of the research, a sample size of 10 was deemed appropriate MALTERUD, K., SIERSMA, V. D. & GUASSORA, A. D. 2016. Sample size in qualitative interview studies: guided by information power. *Qualitative health research,* 26**,** 1753-1760..

intended to be representative, but a cautious exploration of how the dynamics of everyday practice can mobilise certain micro-species entanglements.

In addition to examining parents' descriptions of their behaviours and preferences, and their deployment of particular materials and meanings, the way micro-species come to exercise agency in the performance of practices was studied. A number of complementary research methods were employed to investigate these interactions. First, participants were given 'activity diaries', in which they recorded all activities related to how they conceptualise and endeavour to create a hygienic home, for seven days. The diaries provided a sense of the temporality of practice and the types of activities participants considered relevant to maintaining a hygenic home environment. After completion of the diaries, semi-structured interviews and practice re-enactments were conducted in participants homes. Although the products used by participants, and their constituent chemicals, were recorded, our primary interest was not in measuring molecular interactions, but in how micro-species physically and symbolically interact within and co-construct practices.

The remainder of this paper will introduce findings from this investigation with a focus on four key assumptions about micro-species embedded in the performance of practices. These assumptions are not considered to represent individual judgements or perceived failures, but the ways in which both regimes of hygiene and chemical living are manifesting and being reproduced in this specific context of parental practices.

One: specific micro-species behaviours are assumed to accompany particular activities and material arrangements

One observation consistently noted between participants was that micro-species behaviours are associated with particular common sites of human and animal activity within the home, and that cleaning practices are focused on the material arrangements that structure these sites. Given that micro-species are not immediately detectable by the senses, cues within the observable material environment are used to judge their presence and action. Objects and interior surfaces in the home provide numerous signals that suggest the presence of potential microbial action and hence the need for cleaning. The most consistent proxy for microbes mentioned by research participants was dirt on floorboards and tiles. The majority of participants had floor boards instead of carpet in their living areas, citing them as a cleaner

option that did not ‘hide’ dirt as carpets did. The capacity of floorboards to reveal any kind of viscous or opaque substance they come into contact with, provides immediate feedback on the presence of dirt.

The perception that the floor is likely to be carrying germs, combined with the material signal conveyed by the floor surface that there is something on it, often prompted frequent cleaning with anti-bacterial products. For most participants, the efficacy of a floor cleaning product was judged based on its claims to kill bacteria. When discussing her preferences for floor cleaners Participant 3 stated:

> “At the moment, I'm using Dettol wipes for the floor. I just went into the supermarket looking for something that was antibacterial or antiseptic”

This perceived need to use antibacterial agents in floor cleaning was reiterated by Participant 6 who stated:

> “I was using it (antibacterial cleaning product) on the floor… I felt like it probably needs to be really clean, like with the cats and stuff like that, it just felt like there could be germs. This is antibacterial and stuff. I don't know whether it's psychosomatic or not.”

Similarly, many participants strongly associated kitchen benches with microbial action. Based on the activities recorded in the diaries and the practices discussed and observed, participants reported cleaning kitchen surfaces three times a day on average, even if no physical mess could be seen. The frequent cleaning of benches in the absence of observed dirt suggests an assumption that kitchens, and kitchen activities, generate or attract germs that persist unless there is frequent cleaning. Participant 7 explained that she will clean benches daily even if nothing dirty is perceived, in addition to post meal-time clean up:

> “…probably once a day I'll make sure the benchtops are really clean, so wipe them down and dry them”

The importance placed on frequently cleaning the kitchen was shared by Participant 6:

> "I try and keep the bathrooms clean but I'm not pedantic about it, like I am with the kitchen… you're keeping it healthy for your kids… because there's … food prep a couple of time[s] a day, so it's really nice to start that with a clean everything."

Some participants indicated that that microbes in the bathroom and toilet require the use of particularly strong chemicals, signifying that they perceive the type, and hence behaviour and resilience of microbes, to differ in different parts of the home. Nine participants used bleach or an equivalent anti-bacterial cleaning product in the bathroom that they did not use in other parts of the house. For Participant 9, toilet germs were perceived as persistent and malicious enough to necessitate the disposal of the cloth after cleaning:

> "You know, like wipe (it), chuck it in the bin, because once you've wiped a toilet with a cloth you don't really want to use it again…"

Interactions with animals, particularly pets, were also commonly assumed to accompany encounters with germs. An aversion to microbes that live specifically on animals was observed in accounts participants gave of their children's interactions with family pets. In describing how she protects her daughter from hazards in the home Participant 3 explained:

> "I always put this Dettol stuff on her hands if I know she's been touching the cat bowl."

And from Participant 8:

> "If I've seen that the cat has been lying on the table… That's when I would get the spray out because I think - you know you don't know where they've been."

Contrary to the common perception that the microbes carried by animals are likely to be harmful, recent research suggests that some of the unique types of microbes carried by household pets may be crucial to the development of children's immune systems (Perzanowski et al., 2002, Fujimura et al., 2010). Multiple studies have found that living with a dog as a child significantly decreases the chances of developing allergies (Bufford et al., 2008, Epstein et al., 2011).

These examples of responses to presumed germs on wooden floors, hard kitchen and bathroom surfaces and animals, demonstrate that certain material configurations carry expectations of undesirable microbial encounters. Similar assumptions were also reflected in research by (Greenhough et al., 2018) who engged with citizens in an English town to investigate how and where they conceptualised microbial relations in their homes. In this study, participants indicated that they associated intense microbial action with sites linked to the production of food and disposal of waste, including kitchen bins, door handles, floors, and spaces that have historically been targeted in public health campaigns, such as toilets.

These commonly identified sites of microbial activity have been the target of not only successive public health campaigns throughout the industrialised West, but the values and aesthetics that co-evolved with these campaigns, and informed the design of dirt-revealing home interiors. Maller and Strengers (2013) note that people are often inducted or 'recruited' into domestic practices by their parents as children via the material environment. The way one learns to tell if the floor or shower are dirty, and the process and gestures required to do the dishes or mop the floor often emerge from observing and copying parental practices, and may not be critically questioned as they are reproduced throughout life. As a result, the ways that participants have learned to be affected by material environments, and how they consequently conceive of and maintain them, may result from generations of material engagements in domestic spaces.

The association between intense and potentially pathogenic microbial activity and certain domestic spaces has resulted in the common use of anti-bacterial products in multiple rooms. The frequent application of anti-microbial products to these surfaces has the potential to reduce microbial diversity. Broadly, reductions in microbial diversity in indoor spaces has been correlated with an increased incidence of allergies in children (Heederik and von Mutius, 2012) and more recently, leukaemia (Greaves, 2018). Although little is known about the precise nature of the microbial exposures required to enable human immune systems to develop normally, there is strong correlative evidence suggesting a high degree of microbial diversity in the home is linked with lower rates of these conditions. In addition to altering microbial communities, some anti-bacterial agents such as triclosan and triclocarban have also been linked to endocrine disruption, a process by which certain chemicals begin to participate in the hormonal system, signalling it to develop and act in abnormal ways (Stoker

et al., 2010, Vandenberg et al., 2012). The assumption that anti-bacterial products are necessary in regular, sometimes daily, interactions with floorboards, benchtops and bathrooms may consequently have significant implications for the micro-ecology of the home.

In addition to assumptions about microbes embedded within particular material engagements, participants often relied on a set of sensory cues to determine the presence of micro-species. The following section examines these common sensory signals in greater detail.

Two: the senses can reliably detect harmful micro-species

As discussed in the previous section, participants often assumed that germs accompany particular material arrangements in which 'dirt' or 'grime' are revealed. The visible presence of dirt on a surface thus serves as a proxy for the presence of harmful bacterial micro-species, while clean surfaces are taken to indicate their absence. However, for the participants in our study chemical micro-species seemed to lack a set of such consistent proxies. Rather, the sensable indicators emitted by chemicals, primarily scent, presented them with a confusing and often contradictory set of signals about the relative harm and desirability of different substances.

Among the participants, scent was the most commonly observed method used to detect the presence of potentially harmful chemicals in products. However, chemicals often send confusing messages about potential hazard, as their scents are often carefully engineered to communicate particular product attributes and invoke associations with fresh, fruity and clean environments (Kessler, 2015). The majority of participants indicated that they did not like using products that had a 'harsh' or 'strong' 'chemically' smell around their children, yet they were generally prepared to use products with more pleasing chemical scents. Participant 5 explained that she stopped using some cleaning products after having children due to their 'bleachy' smell:

> "We use to use Domestos for surfaces, to make them nice and clean and kill stuff. Now I just feel like it's too toxic and yucky and bleachy."

She continued:

> "We don't use mould sprays anymore, but we do have some in the cupboard. That's probably the same story as the Domestos, in the sense that I didn't want to use something as potent as that."

These quotes suggest that scent can be experienced as an indicator of the capacity of a chemical to cause harm, its persistence in the environment, and its ability to affect children.

Many of the most hazardous classes of chemicals present in the home environment lack a stable set of sensory attributes, as they transform into different states based on how, when, and by whom they are used. Chemical classes used in cleaning and personal care products that have reported carcinogenic or endocrine disrupting properties, such as antimicrobials, bisphenols, phthalates, and highly fluorinated chemicals, do not become harmful in consistent and linear ways. Rather, their capacity to cause harm is based on what each chemical is combined with in the environment, the age of the body exposed, and how often. For example, common household bleach is relatively benign, however if it is combined with ammonia, drain cleaners, or other acids it produces chloramine gases, which are harmful to human health (Nazaroff and Weschler, 2004). Importantly, how and when a chemical becomes harmful within a given environment is variously determined by 'aggregate exposures' (the effects of cumulative exposures) (Gosens et al., 2014), 'low dose effects' (when a chemical behaves differently in low doses) (Vandenberg et al., 2012) and 'cocktail effects' (when a chemical's behaviour in the body changes based on what other chemicals it is combined with) (Ott et al., 2006). The lack of stable sensory cues for many potentially harmful chemicals means that one cannot safely assume that the potential toxicity of a chemical can be detected through scent.

Reliance on scent as a proxy for potential chemical hazard is additionally problematic because synthetic chemicals are commonly added to personal care and cleaning products expressly to produce effects that make these products seem more effective and desirable. Specific chemical fragrances were effective in convincing many participants of the desirability and efficacy of different types of products. For example, Participant 6 noted that she associates lemon and pine scents with 'hospital-grade' cleanliness, affording a sense of efficacy when present in floor and bathroom cleaning products:

> "…if you're cleaning you're killing the bacteria, but I don't know if it's psychosomatic. It smells like Dettol clean. You feel like…Smell really influences what I buy."

However, scents that Participant 6 describes as "like a hospital floor" were deemed undesirable and did not represent a similar state of cleanliness when used in personal care products. She continues:

> "I like eucalyptus and tea tree smells, but I hate… bleachy, lemony smells, or that piney smell, or anything that smells too chemically I can't handle…in terms of personal care products, there's heaps of smells that I just don't like… I like fruity smells, or natural. I don't like vanilla-ery or sickly-sweet smells, or things that are spicy, like wintery smells. I like fresh smells."

Participant 8 also emphasised the importance of scent as a key determinant of product choice, although she had very different preferences to Participant 6:

> "I'm more likely to pick things based on scent. So if it's a vanilla or a coconut scent, they're my favourites, I would generally pick those… Vanilla - anything with vanilla in it. I'm a sucker for vanilla. I just love vanilla."

These examples demonstrate that culturally developed associations between certain smells and attributes such as 'freshness', leads people to desire particular sensory effects from their cleaning practices.

Although many different natural and synthetic chemicals are used to create product fragrances, The Environmental Working Group's (EWG) review of scientific research into ingredients regularly labelled as 'Fragrance' or 'Parfum' in personal care and cleaning products found they are commonly toxic to organ systems and allergenic (2011). EWG consequently gave Fragrance the highest hazard rating.

The capacity for individuals to detect the presence of harmful chemicals is complicated by the fact that the specific chemicals are generally not required to be revealed on labels due to 'trade secret' regulations. This lack of disclosure, in addition to the inconsistency and

instability of chemical states in the environment, mean that products provide little information, through labelling or sensory attributes, to denote the presence of hazardous chemicals.

More broadly, the issue of unreliable sensory proxies has highlighted the divergence between how micro-species exert agency symbolically and physically in practices. The proxies that have culturally come to represent the presence of harmful microbes (dirt and grime) and chemicals ('bleachy', 'chemically' smells), through a history of socio-material interactions, are not reliable and often provoke actions that lead to more harmful micro-species interactions, such as the use of 'air fresheners' or vanilla-scented anti-bacterial floor cleaners. This discrepancy between how people react to perceived or symbolic micro-species actions that may not physically be taking place, and the actual micro-species interactions with human bodies in the home environment indicates a kind of sensory disorientation. This situation suggests further that individuals should not be held responsible for evaluating potential hazards at the molecular scale.

The following section examines further assumptions in relation to how and when different micro-species act in the home and the consistency with which they are considered to do so.

Three: micro-species are consistent entities

Throughout the interviews and practice re-enactments it was often observed or indicated that micro-species are thought to exist in the home environment and interact with human bodies in consistent ways. All participants engaged in spot cleaning, in response to food or nappy spillages, and routinesed cleaning in which products are used to clean regardless of perceived micro-species activity. The repeat performance of practices intended to remove perceived or imagined micro-species, either consciously or through habitual actions, assumes a degree of consistent micro-species behaviour. However, micro-species often do not act consistently, but respond differently according to changing environmental conditions. Three interlinked assumptions emerged indicating expectations of consistency: first, that the type and rate of microbial recolonisation after cleaning is consistent; second, that chemicals applied dissipate within a short timeframe and are not harmful if they can no longer be smelled; and third, that micro-species primarily enter and affect the body through ingestion.

Inherent in the routinised application of anti-bacterial chemicals is the expecttion that the rate and types of microbial colonisation of an area in the home will be consistent. The use of the same anti-bacterial products in the routine cleaning of a surface or object, assumes that microbes will continue to respond to a product, and re-colonise surfaces, in a uniform way. Given the lack of tangible signals for the presence and activity of microbes, the regular use of cleaning products in routine activities suggests cleaning acts as a form of insurance against potential or assumed microbes. This form of routine precautionary cleaning has been observed in normative cleaning practices since 'germ theory' was popularised (Smith, 2007). However, the regular application of anti-bacterial agents and other chemicals does not necessarily produce uniform outcomes, but can progressively and cumulatively alter the composition of the micro-environment, and the types of microbial communities that become dominant. For example, research suggests that after the application of anti-bacterial products the most resilient types of species of bacteria are likely to survive, thus becoming dominant and potentially resulting in a reduction in microbial diversity (Levy, 2001, Hartmann et al., 2016). This pattern of product application and recolonisation by particular species may be linked to a rise in anti-microbial resistant bacteria found in house dust (Levy, 2001, Hartmann et al., 2016). Practices oriented around the expectation that microbes will all respond to a chemical consistently, regardless of species or the context of application, must be revised if more healthful indoor environments are to be cultivated.

The practices observed and discussed also carried assumptions about the consistency with which chemicals dissipate in the environment and cease to become harmful. For example, Participant 9 explained:

> "I went through a phase where'd I'd clean the bathroom when they (children) were in the bath, because I'm stuck in the bathroom with them anyway, standing there. I might as well clean. Then I stopped doing it, because then the whole bathroom stunk like products. So I'm like, oh my God… I was conscious of them being there, and it stinking like… spray and wipe… I was probably conscious of them breathing in the product, and staying in that room for a while, because they stay in the bath for ages."

In this case, the chemical was assumed to be potentially harmful when the strong 'chemical smell' was apparent in the air, also presumably implying that the chemical would be less

harmful if used when the children were not in the room at the time of application and the chemical scent had a chance to dissipate. Similarly, Participant 6 explained that when she purchased a strong chemical insecticide to exterminate a flea infestation, the chemicals would have left the environment after a couple of days:

> "The bombing is a chemical. It's like a Mortein stuff… I tried to do it last time when we were away for the weekend, and then I did it - I'll do another one this weekend just to be sure, because we're away and it's an opportune time."

However, chemicals can often remain on surfaces and in the air beyond the time that they are able to be smelled, and can enter the body through multiple pathways, in ways that cannot be consistently predicted.

It was also often assumed that using cleaning chemicals is likely to be okay if in small amounts. As Participant 4 notes:

> "I guess I've resigned myself to the fact that a cleaning product has chemicals in it that you don't want to ingest or you know [don't want to come] into contact with. I guess I subliminally allow that into the house; whereas other things I probably wouldn't I guess. I think if I was a big cleaner and I was mopping my floor every couple of days, or once a week even, then maybe I would care."

In addition to assumptions about how much exposure to a chemical is needed before its effects become toxic, and how long the chemical remains present on surfaces after application, there was also a common belief expressed that the primary route route by which chemicals pass into the body is ingestion. Three participants indicated that they thought it was necessary to use surface sprays containing chemicals to remove germs, yet they did not want their children to interact with the sprayed surfaces for a specific period of time after spraying for fear of them ingesting the chemicals. Participant 9 worried that:

> "I don't like the idea of using spray and wipe on this, and then the kids dropping food onto it and eating food straight off it. Because I don't really know what's in the products, and - yeah. So, I think I'm conscious of them touching a product and putting it in their mouth."

The assumption here was that chemical contaminants would become harmful to the child primarily through ingestion, rather than through skin contact, or through the inhalation of aerosolised particles that remain in the air once the product has been sprayed. However, the skin and lungs are also highly effective at absorbing many household chemicals known or suspected to be toxic (Ott et al., 2006).

Another shared assumption was also that the potential harm of household cleaning chemicals can be mitigated if applied only to surfaces that the child will not directly encounter, particularly with their mouths. Participant 1 expressed a belief that using products containing potentially concerning chemicals was okay if not applied directly to the child's belongings:

> "I do look at things and think about, okay, well what am I using this product for and read the label. I mean I do use bleach and things like that but obviously I'm careful about where I use it with the kids and things like that. I use spray and wipe and some of those sort of products as well, but I wouldn't use them necessarily on the kids' things."

She subsequently speculated that 'rinsing' objects or surfaces that have been exposed to chemicals is sufficient to cleanse them:

> "… the washing up detergent you use for plates and cups and things like that… as long as you rinse it it's okay. Whereas I guess the spray and wipe I wouldn't want them to be…(trail off)"

The oral consumption of chemicals may be more concerning to some parents than other routes of absorption because of the potential for immediate and severe poisoning. This message is reinforced through product labels which warn against ingestion, but often provide no safety information about the effects of long-term exposure through the skin or lungs. This focus on the immediate, obscures the long-term cumulative impacts of chemicals.

Perceptions of when and how bodies become permeable to particular micro-species are also influenced by the age of the body exposed. In the following section we examine assumptions related to the way age influences perceived vulnerability.

Four: vulnerability decreases as children begin to walk

Participants perceived that the relative vulnerability of children to different micro-species change as children grow older. The practices observed indicated that parents often assume their children become less vulnerable to indoor environmental hazards, including both chemicals and microbes, around the age of two. However, research suggests they can still in a critical window of vulnerability at the age of five (Landrigan and Goldman, 2011, Crain et al., 2008). Common assumptions have made about how the porousness of children's bodies, or their capacity to be infiltrated by micro-species, changes at different stages of development, influencing what parents allow them to be exposed to.

The role of children's skin as both sensor and boundary was alluded to frequently throughout the interviews. Multiple parents indicated that the sensitivity they initially attributed to their children's skin as babies disappeared as the child became more mobile and begun interacting with a greater variety of materials. For example, Participant 3 stated that:

> "When she (her child) was younger, I was really focused on really gentle stuff on her skin so I used to use (natural brand); it's all natural. Now I really don't care… When they're newborn you just want to be so - you think they're so delicate. When they get older, they're just so robust. She's into everything…"

Participant 8 also shared this assumption that as children grow older and begin walking, they become more 'robust':

> "I think once they get past the age of about two and a half they're like little people. They're not babies anymore. They're talking and they're running around. I think they're probably old enough to use anything now and especially she's not allergic to anything. I don't think it matters."

This perception of robustness not only influences parents' willingness to allow children to interact with more objects in daily life, but also their product choices:

> "When she was a little baby I used special baby products for her skin … As soon as she started kind of coming into the shower with me, that's when we… I just use what I use." Participant 3

Participant 7 also notes that the products she uses on her children changed as they got older. She commented that the older one is "so germy anyway" that she stopped worrying as much about what he came into contact with. Soap and bubble bath are used on the toddler "to entertain" him, however no soap is used on the baby "because it[the baby] is more sensitive". She also suggested a relationship between when her eldest child (two years old) started eating solid food and him becoming more generally resilient.

As parents see their children increasingly interacting with products and surfaces that they previously thought were too harsh or unclean, the absence of immediate illness or health impact may be creating a perception that their children are becoming less vulnerable and it matters less which cleaning and personal care products they are exposed to. Put another way, the lack of direct feedback on how materials actually impact children's bodies at a micro-level, results in the continued use of potentially toxic products. The time delay (often decades) between chemical exposure and the potential bodily manifestation of harm, demonstrates a clear need for assessment mechanisms beyond immediate visible feedback.

As discussed throughout this paper, germophobic hygiene practices are often enacted when no immediate evidence of pathogenic activity available. The persistence of these practices was also observed even where there was verbal acknowledgement that some exposure to dirt or germs is good. Participant 8 stated: "I try not to be a germaphobe", and from Participant 9: "I kind of think that a bit of grime is probably good for them" followed later by "…it's about getting the right bacteria into their system at a really early age, and that actually kind of can protect them from allergies."

However, these beliefs were not generally represented in the practices discussed and re-enacted for keeping the house safe and hygienic, which still primarily focused on the extermination of germs. This occurrence may be related to the findings of (Greenhough et al., 2018) discussed above, that beneficial or probiotic microbial action is associated with particular domestic locations and material arrangements, such as the 'garden', while such positive associations have not been developed for locations such as kitchen floors. However,

it could also be an indication of disparities that emerge between beliefs and attitudes and practices, particularly those that are habitually enacted without conscious reflection (Jack, 2017).

Developing an integrated approach to healthy home micro-ecologies

Investigations of chemical and microbial molecular relations have revealed new disease risks within home practices and infrastructures previously assumed to be safe, and often desirable. To begin to disentangle the practices that reproduce the regimes of hygiene and chemical living in which these relations have been made imperceptible, we have proposed that the integration of concepts from multispecies ethnography and social practice theories can provide a valuable investigative lens. We propose that this approach can assist in identifying operative assumptions within practices that may be generating maladaptive micro-ecologies, contrary to the intent that motivates and perpetuates them. The assumptions discussed in this paper express a number of expectations about how micro-species move and cause harm, and how, when, and for how long human bodies are vulnerable to them. Through understanding the operation of these assumptions in practice, the ways in which they are commensurate with, or contradict scientific knowledge about actual micro-species behaviours can be investigated. By combining this approach with scientific modes of sensing and measuring molecular activity into the future, more nuanced ways of conceptualising the way micro-species culturally and physically participate in, change, and reinforce practices that are contributing to sub-optimal home environments may be better understood.

Homes are intended to function as safe havens from external sources of physical and existential harm. When the notion of the home is ‘inverted’ (Edelstein, 2004) and becomes a source of risk and insecurity it can have profound mental and emotional effects, beyond the physical effects of the risk itself. As conflicting and confusing health messages emerge around the different sources of invisible risk in the home, parents are compelled to negotiate ever more complex relations that are beyond their perception. This paper has shown some of the ways in which parents attempt to sense and manage potentially harmful micro-species based on a set of culturally and materially entrained assumptions about the material conditions under which hazards emerge, and how human bodies become vulnerable to chemical and microbial species. The actions that follow from these assumptions are based on

a profound sense of duty and care for the health of their children; a duty that has been socially framed as their responsibility. As Murphy (2015) highlights, the care work and affective labour often performed by and expected of mothers within families places a unjust burden on parents for managing structural risks beyond their control or responsibility.

As urbanisation accelerates around the world, and growing middle classes increasingly achieve the means to create the healthy and hygienic homes they desire, indoor ecologies will continue to be shaped by the practices thought to create these conditions. To make the micro-species rendered imperceptible by current regimes of hygiene and chemical living legible and political, further efforts to investigate the multitude of ways this imperceptibility is embedded in assumptions, practices and infrastructures across socio-geographic contexts will be required.

REFERENCES

2019. Definition: Species *Oxford English Dictonary* https://en.oxforddictionaries.com/definition/species.

ABRAHAMSSON, S., BERTONI, F., MOL, A. & MARTÍN, R. I. 2015. Living with Omega-3: New Materialism and Enduring Concerns. 33**,** 4-19.

BASHFORD, A. 2003. *Imperial hygiene: a critical history of colonialism, nationalism and public health*, Springer.

BENN, S. 2004. Managing toxic chemicals in Australia: a regional analysis of the risk society. *Journal of Risk Research,* 7**,** 399-412.

BLOOMFIELD, S., STANWELL-SMITH, R., CREVEL, R. & PICKUP, J. 2006. Too clean, or not too clean: the hygiene hypothesis and home hygiene. *Clinical & Experimental Allergy,* 36**,** 402-425.

BRODY, J. G., MORELLO-FROSCH, R., ZOTA, A., BROWN, P., PÉREZ, C. & RUDEL, R. A. J. A. J. O. P. H. 2009. Linking exposure assessment science with policy objectives for environmental justice and breast cancer advocacy: the Northern California Household Exposure Study. 99**,** S600-S609.

BROWN, P. J. C. S. 1997. Popular epidemiology revisited. 45**,** 137-156.

BUFFORD, J., REARDON, C., LI, Z., ROBERG, K., DASILVA, D., EGGLESTON, P., LIU, A., MILTON, D., ALWIS, U. & GANGNON, R. 2008. Effects of dog ownership in early childhood on immune development and atopic diseases. *Clinical & Experimental Allergy,* 38**,** 1635-1643.

CASS, N. & FAULCONBRIDGE, J. 2016. Commuting practices: New insights into modal shift from theories of social practice. *Transport Policy,* 45**,** 1-14.

CRAIN, D. A., JANSSEN, S. J., EDWARDS, T. M., HEINDEL, J., HO, S.-M., HUNT, P., IGUCHI, T., JUUL, A., MCLACHLAN, J. A. & SCHWARTZ, J. 2008. Female reproductive disorders: the roles of endocrine-disrupting compounds and developmental timing. *Fertility and sterility,* 90**,** 911-940.

DARLING, K. W., ACKERMAN, S. L., HIATT, R. H., LEE, S. S.-J. & SHIM, J. K. 2016. Enacting the molecular imperative: How gene-environment interaction research links bodies and environments in the post-genomic age. *J Social Science & Medicine,* 155**,** 51-60.

DAVISON, G. 2008. Down the gurgler: historical influences on Australian domestic water consumption. *Troubled waters: Confronting the water crisis in Australia's cities.* Australian National University Press: Canberra, Australia.

DUNN, R. R., FIERER, N., HENLEY, J. B., LEFF, J. W. & MENNINGER, H. L. J. P. O. 2013. Home life: factors structuring the bacterial diversity found within and between homes. 8**,** e64133.

DUPRÉ, J. 1992. Species: theoretical contexts. *Keywords in evolutionary biology***,** 312-17.

EDELSTEIN, M. R. 2004. Contaminated communities: Coping with residential toxic exposure . Boulder, CO. Westview Press/Perseus Books.

EPSTEIN, T. G., BERNSTEIN, D. I., LEVIN, L., HERSHEY, G. K. K., RYAN, P. H., REPONEN, T., VILLAREAL, M., LOCKEY, J. E. & LEMASTERS, G. K. 2011. Opposing effects of cat and dog ownership and allergic sensitization on eczema in an atopic birth cohort. *The Journal of pediatrics,* 158**,** 265-271. e5.

FOX, E., HITCHINGS, R., DAY, R. & VENN, S. 2017. Demanding distances in later life leisure travel. *Geoforum,* 82**,** 102-111.

FUJIMURA, K. E., JOHNSON, C. C., OWNBY, D. R., COX, M. J., BRODIE, E. L., HAVSTAD, S. L., ZORATTI, E. M., WOODCROFT, K. J., BOBBITT, K. R. & WEGIENKA, G. 2010. Man's best friend? The effect of pet ownership on house dust microbial communities. *The Journal of allergy and clinical immunology,* 126**,** 410.

GOSENS, I., DELMAAR, C. J., TER BURG, W., DE HEER, C. & SCHUUR, A. G. 2014. Aggregate exposure approaches for parabens in personal care products: a case assessment for children between 0 and 3 years old. *Journal of Exposure Science and Environmental Epidemiology,* 24**,** 208-214.

GRANJOU, C. & PHILLIPS, C. 2018. Living and labouring soils: metagenomic ecology and a new agricultural revolution? *BioSocieties***,** 1-23.

GREAVES, M. 2018. A causal mechanism for childhood acute lymphoblastic leukaemia. *Nature Reviews Cancer***,** 1.

GREEN, J. L. 2014. Can bioinformed design promote healthy indoor ecosystems? *Indoor Air,* 24**,** 113-115.

GREENHOUGH, B., DWYER, A., GRENYER, R., HODGETTS, T., MCLEOD, C. & LORIMER, J. J. P. C. 2018. Unsettling antibiosis: how might interdisciplinary researchers generate a feeling for the microbiome and to what effect? 4**,** 149.

GROUP, E. W. 2011. EWG's skin deep cosmetics database. Washington, DC: Environmental Working Group. http://www. ewg. org/skindeep/site/about.

GSPI. 2016. *Six Classes* [Online]. Available: http://greensciencepolicy.org/topics/six-classes/ [Accessed 20 Feburary 2016].

HARAWAY, D. J. 2008. *When species meet*, U of Minnesota Press.

HARTMANN, E. M., HICKEY, R., HSU, T., BETANCOURT ROMÁN, C. M., CHEN, J., SCHWAGER, R., KLINE, J., BROWN, G., HALDEN, R. U. & HUTTENHOWER, C. 2016. Antimicrobial chemicals are associated with elevated antibiotic resistance genes in the indoor dust microbiome. *Environmental science & technology,* 50**,** 9807-9815.

HEEDERIK, D. & VON MUTIUS, E. 2012. Does diversity of environmental microbial exposure matter for the occurrence of allergy and asthma? *Journal of Allergy and Clinical Immunology,* 130**,** 44-50.

HIRD, M. J. 2010. Meeting with the microcosmos. *Environment and Planning D: Society and Space,* 28**,** 36-39.
HUI, A., SCHATZKI, T. & SHOVE, E. 2016. *The nexus of practices: Connections, constellations, practitioners*, Taylor & Francis.
JACK, T. 2017. Cleanliness and consumption: exploring material and social structuring of domestic cleaning practices. *International Journal of Consumer Studies,* 41**,** 70-78.
JEON, Y.-S., CHUN, J. & KIM, B.-S. 2013. Identification of household bacterial community and analysis of species shared with human microbiome. *Current microbiology,* 67**,** 557-563.
KESSLER, R. 2015. More than cosmetic changes: taking stock of personal care product safety. *Environmental health perspectives,* 123**,** A120.
KIRKSEY, S. E. & HELMREICH, S. 2010. The emergence of multispecies ethnography. *Cultural anthropology,* 25**,** 545-576.
LAKIND, J. S. & BIRNBAUM, L. S. 2010. Out of the frying pan and out of the fire: the indispensable role of exposure science in avoiding risks from replacement chemicals. *Journal of Exposure Science and Environmental Epidemiology,* 20**,** 115-116.
LANDECKER, H. & PANOFSKY, A. 2013. From social structure to gene regulation, and back: A critical introduction to environmental epigenetics for sociology. *Annual Review of Sociology,* 39.
LANDRIGAN, P. J. & GOLDMAN, L. R. 2011. Children's vulnerability to toxic chemicals: a challenge and opportunity to strengthen health and environmental policy. *Health Affairs,* 30**,** 842-850.
LEA, T. & PHOLEROS, P. 2010. This is not a pipe: the treacheries of Indigenous housing. *Public Culture,* 22**,** 187-209.
LEVY, S. B. 2001. Antibacterial household products: cause for concern. *Emerging infectious diseases,* 7**,** 512.
LIBOIRON, M. 2015. Redefining pollution and action: The matter of plastics. *Journal of Material Culture***,** 1359183515622966.
LORETZ, L., API, A., BABCOCK, L., BARRAJ, L., BURDICK, J., CATER, K., JARRETT, G., MANN, S., PAN, Y. & RE, T. 2008. Exposure data for cosmetic products: Facial cleanser, hair conditioner, and eye shadow. *Food and chemical Toxicology,* 46**,** 1516-1524.
LORIMER, J. 2017. Probiotic environmentalities: Rewilding with wolves and worms. *Theory, Culture, Society,* 34**,** 27-48.
MAIZELS, R. M. 2005. Infections and allergy—helminths, hygiene and host immune regulation. *Current opinion in immunology,* 17**,** 656-661.
MALLER, C. 2016. Epigenetics, theories of social practice and lifestyle disease. *The Nexus of Practices.* Routledge.
MALLER, C. 2018. *Healthy urban environments: More-than-human theories*, Routledge.
MALLER, C. & STRENGERS, Y. 2013. The global migration of everyday life: Investigating the practice memories of Australian migrants. *Geoforum,* 44**,** 243-252.
MALTERUD, K., SIERSMA, V. D. & GUASSORA, A. D. 2016. Sample size in qualitative interview studies: guided by information power. *Qualitative health research,* 26**,** 1753-1760.
MILLS, J. G., WEINSTEIN, P., GELLIE, N. J., WEYRICH, L. S., LOWE, A. J. & BREED, M. F. J. R. E. 2017. Urban habitat restoration provides a human health benefit through microbiome rewilding: the Microbiome Rewilding Hypothesis. 25**,** 866-872.
MORAWSKA, L., THAI, P. K., LIU, X., ASUMADU-SAKYI, A., AYOKO, G., BARTONOVA, A., BEDINI, A., CHAI, F., CHRISTENSEN, B. & DUNBABIN, M.

J. E. I. 2018. Applications of low-cost sensing technologies for air quality monitoring and exposure assessment: How far have they gone? 116**,** 286-299.
MURPHY, M. 2006. *Sick building syndrome and the problem of uncertainty: Environmental politics, technoscience, and women workers*, Duke University Press.
MURPHY, M. 2008. Chemical regimes of living. *Environmental History,* 13**,** 695-703.
MURPHY, M. 2015. Unsettling care: Troubling transnational itineraries of care in feminist health practices. *Social Studies of Science,* 45**,** 717-737.
MYERS, N. 2015. *Rendering life molecular: Models, modelers, and excitable matter*, Duke University Press.
NAZAROFF, W. W. & WESCHLER, C. J. 2004. Cleaning products and air fresheners: exposure to primary and secondary air pollutants. *Atmospheric Environment,* 38**,** 2841-2865.
NICOLINI, D. 2016. *Knowing in Organizations: A Practice-Based Approach: A Practice-Based Approach*, Routledge.
O'MALLEY, M. A. & DUPRÉ, J. 2007. Size doesn't matter: towards a more inclusive philosophy of biology. *J Biology & Philosophy,* 22**,** 155-191.
OTT, W. R., STEINEMANN, A. C. & WALLACE, L. A. 2006. *Exposure analysis*, CRC Press.
PAXSON, H. & HELMREICH, S. J. S. S. O. S. 2014. The perils and promises of microbial abundance: Novel natures and model ecosystems, from artisanal cheese to alien seas. 44**,** 165-193.
PAXSON, H. J. C. A. 2008. Post-Pasteurian cultures: the microbiopolitics of raw-milk cheese in the United States. 23**,** 15-47.
PERZANOWSKI, M. S., RÖNMARK, E., PLATTS-MILLS, T. A. & LUNDBÄCK, B. 2002. Effect of cat and dog ownership on sensitization and development of asthma among preteenage children. *American journal of respiratory and critical care medicine,* 166**,** 696-702.
PHILLIPS, C. 2014. Following beekeeping: more-than-human practice in agrifood. *Journal of rural studies,* 36**,** 149-159.
POVINELLI, E. A. 2016. *Geontologies: a requiem to late liberalism*, Duke University Press.
QUITZAU, M.-B. & RØPKE, I. J. H. C. 2009. Bathroom transformation: from hygiene to Well-Being? 6**,** 219-242.
ROBINSON, P. A. 2018. Performativity and a microbe: Exploring Mycobacterium bovis and the political ecologies of bovine tuberculosis. *BioSocieties***,** 1-26.
ROOK, G. A. 2012. Hygiene hypothesis and autoimmune diseases. *Clinical reviews in allergy & immunology,* 42**,** 5-15.
ROSE, N. 2007. Molecular biopolitics, somatic ethics and the spirit of biocapital. *Social Theory and Health,* 5**,** 3-29.
ROSE, N., NOVAS, C. J. G. A. T., POLITICS, & PROBLEMS, E. A. A. 2005. Biological citizenship. 439-463.
RYGHAUG, M. & TOFTAKER, M. 2014. A transformative practice? Meaning, competence, and material aspects of driving electric cars in Norway. *Nature and Culture,* 9**,** 146-163.
SAHAKIAN, M. & WILHITE, H. J. J. O. C. C. 2014. Making practice theory practicable: Towards more sustainable forms of consumption. 14**,** 25-44.
SCHATZKI, T. 2016. Practice theory as flat ontology. *Practice Theory and Research.* Routledge.
SCHATZKI, T. R., KNORR-CETINA, K. & VON SAVIGNY, E. 2001. *The practice turn in contemporary theory*, Psychology Press.

SHAPIRO, N. & KIRKSEY, E. 2017. CHEMO-ETHNOGRAPHY: An Introduction. *Cultural Anthropology,* 32**,** 481-493.
SHOVE, E. 2003. *Comfort, cleanliness and convenience: The social organization of normality,* Berg Oxford.
SHOVE, E., PANTZAR, M. & WATSON, M. 2012. *The dynamics of social practice: Everyday life and how it changes,* Sage Publications.
SMITH, V. 2007. *Clean: A History of Personal Hygiene and Purity,* OUP Oxford.
SPACKMAN, C. C. 2018. Formulating citizenship: The microbiopolitics of the malfunctioning functional beverage. *BioSocieties,* 13**,** 41-63.
STEINEMANN, A. 2015. Volatile emissions from common consumer products. *Air Quality, Atmosphere & Health* 8**,** 273-281.
STOKER, T. E., GIBSON, E. K. & ZORRILLA, L. M. 2010. Triclosan exposure modulates estrogen-dependent responses in the female wistar rat. *Toxicological Sciences***,** kfq180.
THRIFT, N. 2016. Understanding the affective spaces of political performance. *Emotion, place and culture.* Routledge.
VANDENBERG, L. N., COLBORN, T., HAYES, T. B., HEINDEL, J. J., JACOBS JR, D. R., LEE, D.-H., SHIODA, T., SOTO, A. M., VOM SAAL, F. S. & WELSHONS, W. V. 2012. Hormones and endocrine-disrupting chemicals: low-dose effects and nonmonotonic dose responses. *Endocrine reviews,* 33**,** 378-455.
WEATHERLY, L. M., GOSSE, J. A. J. J. O. T. & ENVIRONMENTAL HEALTH, P. B. 2017. Triclosan exposure, transformation, and human health effects. 20**,** 447-469.
WILSON, N. K., CHUANG, J. C., LYU, C., MENTON, R. & MORGAN, M. K. 2003. Aggregate exposures of nine preschool children to persistent organic pollutants at day care and at home. *Journal of Exposure Science and Environmental Epidemiology,* 13**,** 187-202.