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RESEARCH ARTICLE



Normalizing novel sanitation practices in transitioning towards circular food and energy systems

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ABSTRACT

Wastewater from sanitation contains several scarce resources that can be reused for purposes of energy and food production. Sanitation infrastructures, however, are often overlooked in debates on circular food systems, while the role of sanitation could be pivotal in combatting resource depletion facing agriculture. Transitioning sanitation infrastructures to support circular systems also needs a thorough understanding of the sanitation practices involved, as resource-oriented sanitation systems require a de-routinization in how we make use of toilets and deal with wastewater. Instead, *novel sanitation practices* are needed for circular developments around sanitation to ensure the reuse potential of wastewater. This research paper focuses on exploring how sanitation practices are shaped and embedded in wider configurations of domestic practices and its implications for the routinization of novel sanitation practices. A mixed-method research design has been adopted studying sanitation practices and infrastructures in three distinct neighborhoods within the Amsterdam Metropolitan Region. First, a survey was conducted that enabled the development of a neighborhood typology. Second, in-depth interviews were conducted to uncover the embeddedness of sanitation practices. Results highlight the importance of normalizing novel sanitation practices when linking sanitation to food systems and list five stepping-stones that may help doing so.

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Social practice; sanitation; food; energy; circularity; sustainability

1. Introduction

With sustainability becoming an ever more pressing global issue, emphasis is increasingly being placed on finding innovative ways to limit society's impact on the environment. As opposed to the linear disposal-oriented paradigm, novel circular developments contribute to this by deeming resource-efficiency, recovery and reuse as crucial to the realization of sustainable water, energy and food systems. Domestic household sanitation could play an important role in such a circular transition, as wastewater contains a number of valuable resources – e.g. thermal energy, nitrogen and phosphorus (van der Hoek, de Fooij, and Struiker 2016) – that can be utilized for purposes of energy and food production. Flushing these scarce resources away in light of depleting phosphorus stocks and increasing resource demands (van der Kooij et al. 2020) is thus at odds with circular goals. Here, a renewal of sanitation infrastructures to ensure efficient resource collection helps in not only capitalizing on the unused potential of wastewater but could also be pivotal to the success of circular systems as a whole.

Developments around sanitation have historically evolved into a dominant design, centered around the quick and invisible removal of human waste from urban areas. This has not only resulted in a technological lock-

in, but this type of sanitation infrastructure has also left a significant mark on our daily lives (Shove and Trentmann 2018). Even something as trivial as going to the toilet has become enacted against the backdrop of historical developments that have given shape to our current network of sewage pipes and treatment facilities. For instance, our current practice of toilet use in the developed world is largely characterized by the 'flush-and-forget' principle (Hegger 2007); where we have habituated the idea that urine and feces need to be smoothly and invisibly disposed of. Such a notion has only been able to become embedded in toilet practices due to the parallel mainstreaming of large-scale sewer infrastructures and high sewer connection rates in most parts of the western world.

Resource-oriented sanitation, on the other hand, comes in a variety of forms and functions, ranging from low-tech, small-scale decentralized systems to larger and more high-tech centralized networks (Abbassi and Baz 2008; Hegger, Van Vliet, and Van Vliet 2007). Examples of developments in this field are onsite sewage facilities (OSSF) using reedbed filters, vacuum toilets connected to a bio-refinery, urine separation toilets and modern-day adaptations of composting toilets. Additionally, by either making resource recovery from sanitation possible or by

directly linking wastewater to energy/food systems, most of these current developments are thus set in a context of circularity.

The ongoing innovation around resource-oriented sanitation should take into account the historically grown mundane sanitation practices and how they are expected to change alongside the adoption of new sanitation technologies (Brand 2005; Hegger 2007; Van Vliet, Spaargaren, and Oosterveer 2010). Currently, we routinely flush toilets using large amounts of water, we use chemical toilet cleaners, and sometimes we even flush solid wastes such as leftovers or wet wipes – practices which hamper the transport and processing of wastewater. Moreover, as innovative sanitation options link sanitation infrastructures to energy or food systems, this also means a break with current socio-cultural norms and conventions rooted deeply within our sanitation practices. Particularly, reusing wastewater (products) for the production of food is likely to touch on some (perceived) health risks incurred by possible pharmaceutical residues, viruses and pathogens present in human excrements (Cai and Zhang 2013; H. Jones, Voulvoulis, and Lester 2005). Similarly, calls for dealing with wastewater products in our daily sanitary routines (e.g. localized forms of reuse) reveal a societal taboo with regards to changing the quick and ‘invisible’ flush-and-forget disposal of human waste (Van Vliet and Spaargaren 2010).

The specific way of ‘doing’ sanitation is thus situated in an intimate web of perceptions, emotions, meanings and belief structures. Hence, transitioning sanitation systems to become part of circular systems entails not only the need to have an eye for sanitary technological developments, but also for the social embeddedness of sanitation practices. Whereas previous literature has largely taken a technology acceptance stance regarding novelties in sanitation (Anand and Apul 2014; Naus and van Vliet 2012; Reinink and Kempener 2001; Telkamp, Mels, and Bulk 2008), a more thorough assessment of sanitation practices linked to circular thinking is still missing. Resource-oriented sanitation systems namely require a de-routinization of current practices; meaning that a novel way of using the toilet itself and dealing with wastewater – here referred to as *novel sanitation practices* – needs to become a normal part of daily routines.

This paper sets out to understand how a shift to resource-oriented novel sanitation practices is constrained or enabled by the performance of both the current and these novel sanitation practices. Such an understanding is needed to develop better-informed innovation in sanitation in advancing circularity, while shifting the focus from sanitation technologies towards sanitation practices. Central to this research are three distinct neighborhoods within the Amsterdam Metropolitan region, each characterized

by a different sanitation infrastructure and circular orientation. Within these neighborhoods we question how sanitation practices are given shape, how they are embedded in daily routines and structures, and subsequently what this implies for the normalization of novel sanitation practices.

The paper is built up as follows; firstly, we build connections between different practice theories to support the analysis. Secondly, we introduce our three case-study neighborhoods and detail our methodological approach. Thirdly, our results are presented, which include a typology of the neighborhoods and the analysis of the (novel) sanitation practices. Finally, in the discussion and conclusion we reflect on our results.

2. Theoretical framework

The most important body of literature to help explain any variations with respect to the development of user practices is social practice theory. Numerous authors have contributed to this field of study. Reflecting on early works of Bourdieu, Giddens and others, Reckwitz (2002) defines practices as routinized activity ‘*which consist of several elements, interconnected to one other: forms of bodily activities, forms of mental activities, “things” and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge*’ (Reckwitz 2002, 249). These activities are not static, but are open to change throughout time and space, as Schatzki (1996, 89) theorizes practices as an ‘*open-ended, spatially-temporally dispersed nexus of doings and sayings*’. In turn, these practices are affected by their practical and general understandings, rules and teleoaffective structures (Spaargaren, Weenink, and Lamers 2016). Where practical and general understandings refer to knowing what to do and how this is understood in light of wider beliefs and concerns, rules represent the (implicit) norms on what is desirable and tolerable. Finally, teleoaffective structures ‘*is about being goal-oriented, where the goal is directed by normative views or moods*’ (Gram-Hanssen 2010, 48). In short, this means that practices are not only the bodily activities such as doings and sayings, but comprise of societal, goal-oriented, structural and individual elements.

Figure 1 visualizes how practices are shaped by, and co-shape the structural and individual elements that are at play – e.g. the infrastructural provisions, rules, teleoaffective structures, lifestyles, norms and the socio-technical system as described by various authors (Giddens 1979; Spaargaren and Van Vliet 2000; Spaargaren, Weenink, and Lamers 2016). Here, the way in which toilet practices are given shape is affected by how daily routines are performed and the norms and values that surround this (lifestyle),

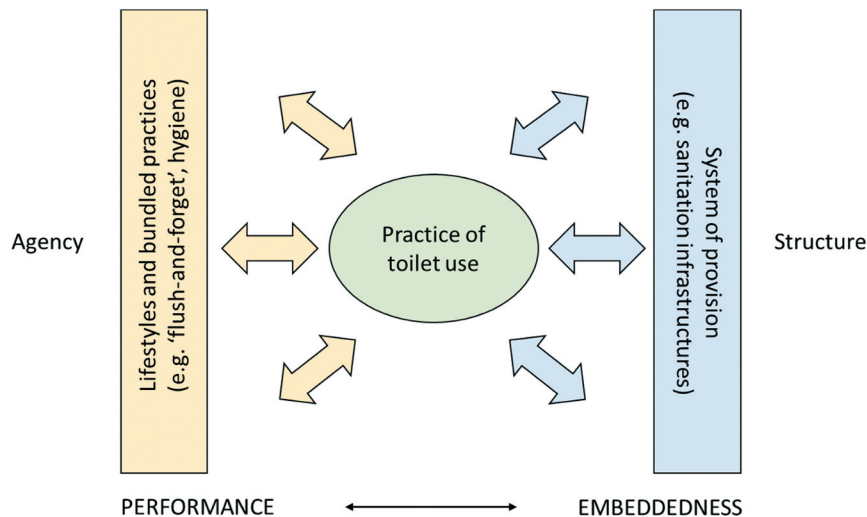


Figure 1. Dialectical interaction of agency and structure on the configuration of sanitation practices. adapted from (Spaargaren and Van Vliet 2000).

together with how certain ways of doings are institutionalized and embedded within specific infrastructures (system of provision). It is through this dialectical interaction that we are able to understand how practices are normalized based on the wider individual, societal and structural contexts. Simultaneously, it helps in understanding how sanitation practices are constrained and enabled by both physical infrastructures and individual preferences. This means that a change in sanitation infrastructures must align with standardized lifestyles present in society and the hygienic conventions and preferences that it holds high (Spaargaren and Van Vliet 2000). Similarly, a change in lifestyle may also be met with appropriate technological innovation. The role of sanitation in circular energy or food systems requires a mutual evolvment of both lifestyles and infrastructures for novel sanitation practices to become successfully normalized.

While the above discussion helps in understanding and contextualizing sanitation practices, the framework by Pantzar and Shove (2010) is used as guidance throughout the analysis, as it enables an effective classification of the practice components found. According to them, practices consist of three distinctive elements: materials, meanings, and competences. Firstly, materials refer to the physical aspects involved in practices, such as equipment, infrastructure, the body and artefacts – e.g. sanitation in the case of this paper. Meanings then, represent the symbolic images and cultural connotations associated with certain activities. Lastly, competences refer to the skills and knowledge required for the performance of the practice (Pantzar & Shove, 2010). Knowing these three elements of practices helps in understanding not just how sanitation practices are given shape, but also how and why citizens come to use different sanitation systems.

Yet, zooming in on how toilet practices are constituted only tells half of the story. As Nicolini argues, *'understanding and re-presenting practice also requires providing an appreciation of the connectedness of practice and the fact that activities never happen in isolation, so that practices are always immersed in a thick texture of interconnections'* (Nicolini 2009, 21). For instance, toilet practices are connected to a variety of other 'bundles of practices', such as supplying, installing and maintaining the sewage infrastructure, or – in the case of nutrient recycling – the composting and gardening using organic matter. Complementary to zooming in on sanitation practices, zooming out on bundles of practices makes it possible to assess how the normalization of novel sanitation practices is enabled or inhibited.

3. Methods and material

We started the research in purposely selected neighborhoods to explore variation in terms of how sanitation practices are performed, as we made the presupposition that citizens who are engaged in resource efficiency and circular systems would also perform sanitation practices differently. The three distinct case study neighborhoods were selected along criteria illustrated in Figure 2. Firstly, each neighborhood represents recent residential development, with houses being constructed within the last decade, which required new residents to consider their sanitation fittings. Additionally, the selection was based on whether citizens were confronted with novel resource-oriented sanitation systems during the development and construction of their houses. A distinction is made between households connected to mainstream sewage infrastructure, and households with an alternative or no sewage connection at all. Further, the neighborhood selection was based on the circular orientation of

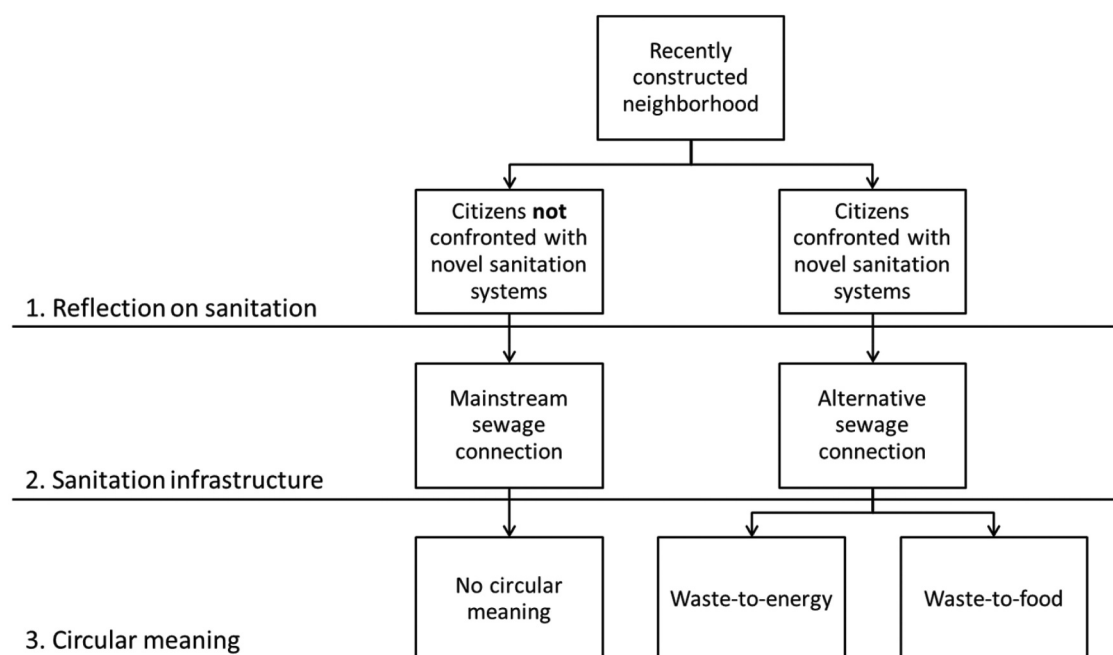


figure 2. Scheme depicting the sampling cluster selection based on circular meanings. each cluster (no circular meaning, waste-to-energy, waste-to-food) represents a different neighborhood.

the neighborhood sanitation infrastructure; specified as having a circular waste-to-energy or waste-to-food focus, as opposed to having no circular orientation at all.

The first neighborhood, Almere Poort, comprises of mixed newly constructed housing (since 2007), including both dense urban apartment blocks as well as private detached houses. Located between the IJmeer and Almere city, the 8.6 km² neighborhood consists of approximately 6,500 households and 15,000 residents as of 2019 (CBS 2019). The development of this neighborhood had no central focus on sustainability or circularity – apart from some individual investments in household retrofitting. Contrary to the other two neighborhoods, Almere Poort is connected to the sewage infrastructure and regional wastewater treatment system. This is the most profound distinction between Almere Poort and the other two areas.

The second neighborhood, ‘Schoonschip Buiksloterham’, represents a circular waste-to-energy neighborhood. Located in the Buiksloterham district in Amsterdam Noord, it is a circular (floating) residential area that is being constructed based on ‘novel’ sanitation infrastructures and in-home sanitary fittings (Gemeente Amsterdam 2016). To recover waste for energy, the wastewater is separated at the source (at the household level) into black (toilet waste) and grey water (all other wastewater) streams. Subsequently, the black wastewater is directed to an onsite bio-refinery that ferments the waste and transforms it into energy (Schoonschip Amsterdam 2019b). The ‘Schoonschip’ project has a projected total of 46 addresses; a little over 100 residents (Schoonschip

Amsterdam 2019a). At the time of writing, the bio-refinery was yet to be installed, but separated wastewater infrastructure and vacuum toilets were already in place.

The third neighborhood, Almere Oosterwold, represents a circular waste-to-food neighborhood. It is a 43 km² peri-urban development area in which new residents are required to develop their own of sanitation systems as government-regulated sewage and water infrastructure is intentionally absent. Ultimately, Oosterwold will provide for 15,000 houses (Gemeente Zeewolde & Gemeente Almere, 2013). During the period of data collection, many sites and houses were still in development. The aim of project Oosterwold is to build a sustainable ecosystem by closing the loops; thereby making sure wastewater is reused locally without damaging the environment (Gemeente Almere, 2016). In addition, Oosterwold has a significant focus on food production; with 50% of each plot assigned to urban agriculture. When completed, Oosterwold should be able to provide 10% of the regional food demand (Jansma and Wertheim-Heck 2021).

3.1 Methodology

In assessing the normalization of novel sanitation practices based on our three case study neighborhoods, we deployed a two-step approach.¹ We started (step 1) with a preparatory survey to explore the distinction between neighborhoods in properties related to (i) household sanitation infrastructures, (ii) household sanitation practices and (iii) their attitudes towards sanitation in relation to circularity. The survey did not aim to

provide statistical validity in cross neighborhood comparisons (see for respondent inclusion Figure 2), but served the purpose of typologizing the distinct neighborhoods; providing more detailed information on the characteristics of the three neighborhoods at household level (see SM 1 – Survey questionnaire). First the survey assessed the aspects that citizens find important about their toilet, such as water savings, costs, or ease of cleaning. Subsequently, statements relating to the use of different types of (resource-oriented) sanitation systems and to the perception of different wastewater applications were rated on a 5-point Likert scale. The survey included 91 respondents, of which 54 were citizens from Oosterwold, 9 from Buiksloterham, and 28 from Almere Poort.

Next (step 2), being the core of this research, qualitative in-depth and semi-structured interviews combined with in-home household sanitation observations were used to uncover the deeper (teleoffective) meanings, competences and material elements that constitute the performance of practices. We first zoomed in on the sayings and doings related to the householders' sanitation practices. Subsequently, we zoomed out on their relation to sanitation infrastructures. To capture the variation in sanitation infrastructures in the three case study neighborhoods, interviews were conducted with householders from all three neighborhoods. Eight households have been visited in situ, with five interviewees in Oosterwold, one interviewee in Buiksloterham, and two interviewees in Almere Poort.

Households were included using convenience and snowball sampling methods. This included contacting residents through online platforms such as Facebook and LinkedIn, and through the distribution of flyers in the respective neighborhoods. To guarantee anonymity when referring to interviewees, quotes only specify the neighborhood and type of toilet. The fact that

Buiksloterham accounts for the smallest number of respondents in both the survey and the interviews is primarily due to the smaller total population size of this neighborhood (N=46). Moreover, citizens could not be contacted face-to-face as many houses seemed to still be uninhabited at the time the research was conducted. Research fatigue was another factor that may have hampered sample sizes. These lower numbers limit the representativity of the findings, but results from the survey and interviews are principally used to explore the diversity and variation by employing a qualitative practice-based approach, not to attribute statistical validity to its findings. Since the aim is to capture variation, fewer interviews were thus needed in Buiksloterham – where all households have the same sanitation infrastructure – as opposed to Oosterwold.

4. Results

4.1 Typology of households in neighborhoods

Starting with the non-circular neighborhood, houses in Almere Poort primarily have regular flush toilets, either with or without dual flush systems. In Almere Poort, the ease of cleaning was considered the most important trait of a toilet, as was mentioned by most of the respondents. Moreover, water usage and comfortability were also of medium to high concern to this neighborhood. As for toilet use, a relatively large proportion of respondents indicated that they want to flush substances such as leftovers and wet wipes (see Figure 3). Similarly, respondents in Almere Poort had a tendency to use chemical toilet cleaners, such as toilet duck or toilet blocks. Most respondents also didn't see the use of composting toilets as something positive and a majority indicated they think of composting toilets as smelling badly.

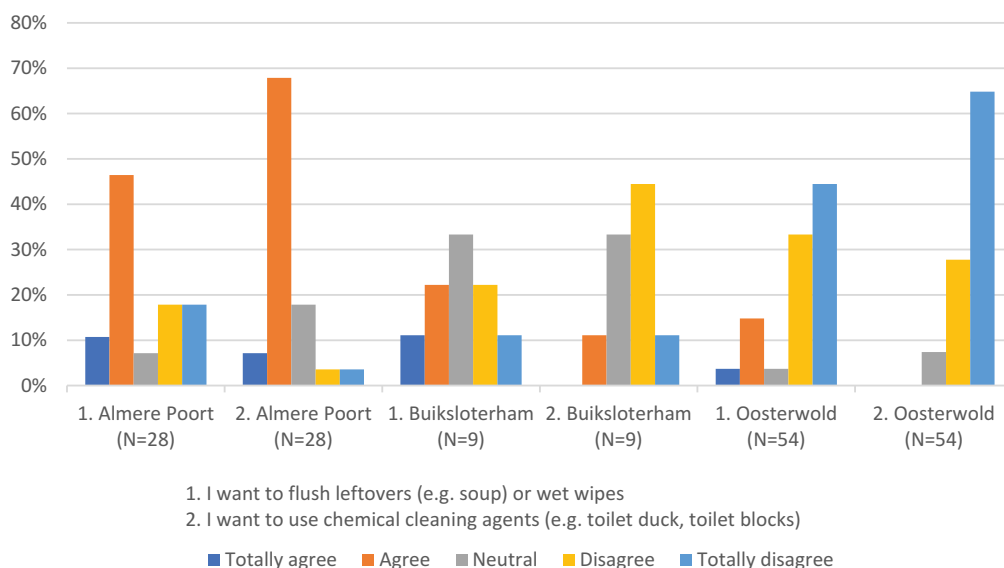


Figure 3. Perceptions towards flushing leftovers, wet wipes and using chemical cleaning agents. data per neighborhood.

Thinking of novel sanitation practices in the sense of actively reusing human waste, the willingness to give up on comfort and/or ease of use in order to facilitate such practices was very low. In general though, attitudes towards reusing wastewater for energy production were very positive. On the other hand, despite the fact that respondents in Almere Poort had a relatively positive attitude towards composting human waste in general, only a minority ($N = 6$) expressed the willingness to engage themselves in the practice of fertilization using composted human waste – no one actually doing so. Finally, considering the consumption of food, attitudes towards consuming foods cultivated with the use of composted human waste as fertilizer were negative.

In Buiksloterham, everyone had to adopt novel sanitation technology in the form of vacuum toilets. Low water usage was mentioned by all respondents as an important aspect of a toilet. These results are not surprising considering how this neighborhood solely involves residents taking part in the ‘Schoonschip’ project, which is centered around floating homes and the use of vacuum toilets. Similarly, all respondents were positive about the use of vacuum toilets. However, all of them also considered vacuum toilets to make too much noise while flushing. Moreover, all Buiksloterham respondents were in favor of converting human waste into compost – despite them focusing primarily on waste-to-energy solutions. A vast majority was also positive towards using composted human waste for fertilizing consumable plants such as fruits and vegetables. This translates itself into half of the respondents being open to reusing composted urine and feces for the fertilization of their own garden. Finally, a majority of respondents didn’t see a difference between reusing human waste from neighbors or from one’s own.

Lastly, all households in Oosterwold were connected to onsite sewage facilities (OSSF, or ‘IBA’ in Dutch) such as reedbed filters, or advanced septic tanks. However, the majority of households in Oosterwold did opt for a regular flush toilet, with only a few respondents opting for a composting or a urine-separation toilet. So, even though sanitation infrastructure on household level (type of toilet) remained largely standard, sanitation infrastructure on a neighborhood level (sewage connection) is characterized by onsite wastewater treatment. Furthermore, as opposed to Almere Poort, only a few respondents actually expressed the willingness to flush substances such as leftovers or wet wipes, and none of the respondents expressed the willingness to use chemical cleaning agents (Figure 3). Turning to the use of composting toilets, less than half of the respondents found a composting toilet smelly and difficult to keep clean, and a similar share was positive about its use. The actual perception towards the reuse of composted human waste was mixed. Namely, whereas respondents in Oosterwold were generally in favor of converting urine and feces into compost, they had more negative

attitudes towards reusing composted feces for consumable plants or the consumption of such plants (Stehouwer, 2020).

4.2 Mundane sanitation practices

Although the three neighborhoods central to this paper have been selected based on their differences with regard to engagement in circular systems, they all have one thing in common. Namely, all three neighborhoods are relatively newly constructed residential areas. This means that most residents have recently been involved in planning and decorating their exterior and interior house. During this process, citizens are confronted with a moment of reflection in which they (un)consciously consider the performativity of their sanitation practices – i.e. at such a moment prior acquired knowledge, conventions and ideas concerning the use of sanitation become materialized into the design and functioning of their toilet. In this way, citizens from these three neighborhoods serve as the skilled, knowledgeable and competent agents whose insights help in obtaining a better understanding of the practice elements that either inhibit or enable an innovation of circular sanitation systems.

4.2.1 Cleanliness and Hygiene

The material toilet bowl itself has historically evolved into the white and round design that we directly link to hygiene today. Recent innovations in the design of the toilet bowl have largely focused on increasing convenience related to the maintenance of sanitary hygiene, such as hanging or rimless toilet bowls. Associated with this development is also the historic evolution of the practice of cleaning, which now involves the application of toilet cleaner or bleach (e.g. using the turned neck of toilet cleaners), giving it some time to ‘eat away’ all bacteria and stains, and subsequently brushing the inside of the bowl using a toilet brush. In addition, many people install rim blocks in order to clean and freshen the bowl during every flush.

The practice as described above, however, is a phenomenon that has only developed recently. Since the World Wars, emphasis has increasingly been placed on developing hygienic sanitary behavior (Bay 2019; Black and Fawcett 2008; Sundnes 2018). Simultaneously, the marketing industry has made toilet cleaners and fresheners an important part of our hygienic toilet routines – e.g. most households have a bottle of toilet cleaner within reach of the toilet. This way of maintaining sanitary hygiene is imprinted in our routine to the extent that we barely question its purpose. Spraying some toilet cleaner is found just as normal as refueling a car; it is done without questioning.

So to say, our current way of cleaning the toilet and the unequivocal link with hygiene and freshness is socially constructed. It has been taught and passed

on, and has led to the embeddedness of hygiene and chemical toilet cleaners in our sanitation routines. These specific 'doings' have been ingrained so deep into our minds that we find it hard to think otherwise. The application of bleach is perhaps one of the best examples to illustrate how deeply embedded certain ways of doing are. In the excerpts below the use and smell of bleach and toilet cleaners is directly associated with cleanliness. For instance, the application of bleach reassures the interviewee of the fact that the toilet is clean – i.e. when he smells bleach, he instinctively thinks of cleanliness and hygiene.²

- (A) *'I use toilet cleaner. The home brand of a supermarket. I have used eco, but I didn't like that one. [...] I didn't find it that clean. And it didn't smell that nice'* (Oosterwold, Regular flush toilet).
- (B) *'... weekly a wet cloth with soap is wiped over the outside of the bowl. The bowl itself is done with the toilet brush, a squirt of bleach and then some scrubbing and flush ... I'm also someone who likes another squirt of bleach under the rim. [...] If it can be done more environmentally-friendly, I am willing to think about it. But I really can't think differently about it then with bleach, and I think that the treatment facilities are good enough to remove it. It still needs to get clean'* (Almere Poort, Regular flush toilet).

Even when the environmental impact of using bleach is contemplated, the interviewee reaffirms his practice by telling himself the water treatment facilities will know how to remove bleach from wastewater. The indisputable connection between toilet cleaner and hygiene – although often considered the norm – is thus at direct odds with the environment. We may know that using these substances could be harmful for the environment, yet we convince ourselves that it is an inherent part of cleaning the toilet: *'You try to use it in a normal fashion, but washing a car without soap is also not possible'* (Almere Poort, Regular flush toilet).

Cleaning the toilet is a practice that usually takes place once the toilet is considered in need of better hygiene. In addition, people may also have grown accustomed to certain behavioral acts that are more 'continuous' ways of maintaining sanitary hygiene. These acts are performed each time someone goes to the toilet. An example of such an act is the 'building of a raft' as a way to prevent skid marks and thus make maintaining hygiene easier:

"For the sake of hygiene and easiness of cleaning we try to teach them [the kids] to build a raft, because then you have fewer skid marks. So, lay down a single sheet of toilet paper and try to aim for that ... 2-3 sheets of toilet paper. It doesn't need to be a giant pile of toilet paper. Just place them on the edge where the bowl meets the water." (Almere Poort, Regular flush toilet).

Interestingly, the practice described above is situated within a context of a family with young children. The issue with children is that they might not always take the brush and remove skids marks after they have gone to the bathroom, while it are particularly children that tend to create the most skid marks. Small children are not directly placed with their bottoms above the water, since the toilet bowl is designed for adults. The material design thus plays a role in configuring how the practice of maintaining sanitary hygiene is enacted. The practice of maintaining hygiene by creating rafts should be seen both in the context of having children and the material infrastructure.

An important note to take away from this is that practices have been formed depending on wider structures, lifestyles and technical artefacts, and through understanding how practices are developed within these contexts we get an idea of what this could imply for sanitary infrastructures. Knowing why and how a practice is performed – e.g. creating rafts – helps to reveal potential implications for the material design of the toilet itself. For instance, having children and teaching those children to prevent skid marks, tells us that the toilet's design is not functioning according to their hygienic belief structures. The parents don't want skid marks, yet having children requires them to practice creating rafts, since the design of their toilet bowl does not facilitate children's bottoms.

4.2.2 Flushing and Water Saving

Today, almost all toilets are connected to a water supply for flushing. This is a result of a desire to remove human waste from urban neighborhoods, and a century-old consolidated system of flushing wastewater through sewer systems. Although this development has helped to combat diseases such as cholera, it has made flushing toilets a necessity for the waste to be transported down the sewage. Subsequently, the idea of flushing has become a habituated practice.

The introduction of dual flush systems has set the stage for a more conscious reflection on the practice of flushing. Nowadays, people are offered a choice each time they visit the toilet: *'We have a toilet with a split button, so you ask yourself do I need a lot of water to flush or not?'* (Oosterwold, Regular flush toilet). This way of flushing has been normalized in society as it does not conflict with our habituated practice of flushing. Flushing remains an integral part of toilet practices and dual flush systems do not interfere with this desire to flush. This has to do with the way in which people legitimize certain practices and come to collectively participate in the performance of these practices. Shared meanings about the use of dual flush systems are developed socially, and their use depends on how it is operated within an existing network of routines and understandings (May & Finch, 2009).

People normalize the use of dual flush systems as it does not conflict with prior held beliefs and understandings about toilet practice – such as cleanliness and ‘emptying the bowl’. In a sense, the practice of dual flushing is ‘transferrable’. People can be ‘bought-in’ to that practice and are thereby reiterating current hygienic notions about what toilet practice entails. This way, dual flush systems have become normalized.

Together with the rise in dual flush systems, awareness in terms of water usage has also risen. Whether environmentally or financially motivated, saving water by being aware of the frequency and quantity of flushed water has become a meaning that is connected to current sanitation practices:

“... it is important that it [the poo] is immediately gone, but I’ve once read this sentence: ‘if it’s not smello you can mello’ or something like that [the interviewee probably referred to the saying: ‘if it’s yellow let it mellow, if it’s brown flush it down’]. You know, three wees can be put on each other, instead of one wee – one flush. That is what we do when we and the children go to bed. And [referring to the dual flush] we also say, guys listen; that one is for the wee and that one is for the poo. That is important.” (Almere Poort, Regular flush toilet).

In other words, urine is seen as something that is less ‘dirty’ as compared to feces. This way, it is more acceptable to combine people’s wees in order to only flush a single time. Smell plays a meaningful role here, as a smelly output invokes emotions of disgust and uncleanness, whereas a less smelly output such as urine doesn’t necessarily have to be flushed away. Conversely though, there is a certain discrepancy between saving water and using bleach. Namely, whereas the saving of water seemingly sounds like a way of being aware of the environmental impact, this kind of behavior is sometimes compensated by using bleach:

“In principle, it doesn’t really matter if a wee stays in the bowl. Does it leave a yellow stain? Well that’s where you have the bleach for in the toilet.” (Almere Poort, Regular flush toilet).

Even though the above interviewee considers it important to save water, and hence is perfectly fine with accumulating urine in his toilet bowl, he does use bleach in order to compensate for the fact that this kind of behavior might leave yellow stains. This indicates the environmental ambivalence between saving water and using bleach. The historically grown mundane notion of cleanliness appears to dominate the sanitation practices, not the specific environmental implications.

4.3 Novel sanitation practices

4.3.1 Using resource-oriented sanitation systems

The neighborhoods of Buikslooterham and Oosterwold are, compared to Almere Poort, much more focused on resource-oriented sanitation and circularity.

Subsequently, novel sanitation practices are – to a certain extent – expected to be performed here for two reasons. Firstly, reflection on the type of sanitation infrastructure in a neighborhood may attract a certain kind of people with specific (goal-oriented) circular meanings and competences:

(A) *‘I used to live on a boat in Rotterdam. [...] You won’t believe it, but you were allowed to dump everything in the river Meuse, which is connected to the sea. [...] That’s when I realized that I was actually feeding the fish. So even my toothpaste was organic. I had a septic tank, but it’s content was actually also pumped in the Meuse’ (Buikslooterham, Vacuum toilet).*

(B) *‘In theory, most people who live here are environmentally-friendly, otherwise you wouldn’t choose to live here’ (Oosterwold, Japanese flush toilet).*

Secondly, the disruptive switch to either an OSSF connection, a composting toilet, or a vacuum toilet could come to alter the ways in which citizens make use of the toilet. For instance, being disconnected from the main sewage system and having responsibility for one’s own OSSF spurs people to reflect upon the performativity of toilet cleaning more consciously:

“Previously, we more easily used cleaning agents such as toilet duck, or whatever. With the idea like that it was needed: you flush it away and it’s gone, you never see it again” (Oosterwold, Regular flush toilet).

A certain de-routinization of cleaning is thus taking place once people are confronted with a change in their material infrastructure. No longer are the consequences of using chemical cleaning substances ‘out of sight, out of mind’, but now these consequences are unfolding right in people’s own backyards. This leads to increased awareness of people’s own practices, and their prior held practice links such as bleach or toilet cleaner and hygiene become disconnected. People who chose to live in Buikslooterham or Oosterwold may attribute already more meaning to sustainability and circularity, even though we see that using an OSSF changes both the meaning (hygiene and cleanliness) and material components (chemical toilet cleaners) in household sanitation practices. Competences also play an important role, because citizens need to acquire new knowledge related to the specifications of the system and the quality of their effluent. In order to maintain the quality of the OSSF, citizens need to understand the potential harmful effects that specific toilet cleaners can have on their system. Incomplete and disputed knowledge on this leads some interviewees to abolish the use of chemical toilet cleaners entirely from their sanitation practices. Others, of

whom the application of toilet cleaners was more intricately linked to meanings such as hygiene and convenience, had a harder time giving up on the use of toilet cleaners.

Before moving on to the use of composting and vacuum toilets, it is important to reiterate the distinction made between sanitation infrastructures on neighborhood level (sewage connection), and sanitation infrastructures on household level (type of toilet). Citizens connected to an OSSF, for instance, often continue to use regular flush toilets, which entails that they still maintain a degree of the 'flush-and-forget' principle – although now also becoming more aware of where it is flushed to. Contrary to this, composting and vacuum toilets no longer facilitate such thinking. In a sense, where the introduction of OSSF reframes the thinking from 'flush-and-forget' to 'flush-and-remember', the introduction of composting and vacuum toilets takes it one step further and places the locus inside of the household.

Where brushing, applying toilet cleaner and flushing usually suffices for a regular flush toilet, a composting toilet requires additional handlings such as emptying the bucket and subsequently rinsing and wiping the bucket clean with soapy water and a cloth. Furthermore, urine is more or less odorless, but leaving feces in the toilet bowl creates a stench that is usually perceived as undesirable. The fact that it might be perceived as such entails that we have been taught specific skills and competences that help us in keeping the toilet smelling fresh. Similar competences are involved in the use of composting toilets. Here excrements are collected and left within the toilet itself while toilet cleaner is replaced by wood chippings for the purpose of avoiding smell. Yet, where toilet cleaner adds a freshening citrus or pine odor, using wood chippings just neutralizes bad smell, but does not replace these bad smells with freshening odors. The meaning of hygiene must thus change with the introduction of composting toilets – i.e. for the user of a composting toilet it is not the presence of a fresh odor that is associated with cleanliness, but the absence of a bad smell. Currently though, freshness plays such an important role in our sanitation practices that it's embeddedness constrains the use of composting toilets:

"Despite the fact that you hear different stories about its smell, it is our experience that it stinks. [...] If you don't remove it each time, it stays in your toilet bowl. And that's something we didn't find a pleasant idea. We simply didn't choose for it" (Oosterwold, Regular flush toilet).

Vacuum toilets, on the other hand, enable a quicker and more efficient disposal of human waste; thereby adding to the significance of cleanliness. However, even for vacuum toilets a de-routinization of current sanitation practices must take place. The way vacuum toilets flush means that some excrements might remain in the

toilet bowl (skid marks) as an insufficient amount of water is used in order to effectively clean the entire bowl. This again has implications for the way in which notions such as cleanliness and hygiene must be interpreted. For instance, where in Almere Poort leaving urine in the bowl was found to be relatively acceptable, it was stressed that feces would still need to be flushed. Moreover, skid marks were actively prevented through the building of rafts and brushing. Yet, as stressed by an interviewee from Buiksloterham, his vacuum toilet and his desire to save water means that residue marks in the bowl have become more accepted. Instead of immediately cleaning the bowl after use, he routinely accepts leaving some skid marks, which he successfully knows how to erase during a subsequent urination visit.

4.3.2 Sanitation as part of circular systems

How our daily sanitary routines are given shape when using resource-oriented sanitation systems is just one side of coin. In addition, linking sanitation systems to energy and food systems requires re-evaluating current forms of human waste management and re-addressing the conventions and ideas in which they are situated. As highlighted in Table 1, especially the use of human waste for agricultural purposes may encounter some social stigma. Whether citizens are actively or passively taking part in novel sanitation practices, the following section will discuss how ideas of vulgarity and perceived risks come to play an important role within such sanitation-food systems.

Perhaps a composting toilet is the best example of how citizens can be actively involved in the practice of human waste management. Yet, it simply doesn't make sense for people to actively participate in the practice of handling and reusing excrements when they are so keen on flushing them straight away for the sake of hygiene – unless they are truly committed to improving the environment. The meaning of 'distance to the user' plays an important role here with respect to how gross the practice of reusing feces is perceived. Excrements from someone's own are considered less repulsive as compared to excrements from the rest of the neighborhood (A), while reuse for energy production instead of food production is perceived much more favorable (B).

- (A) *'Yes I think that the further it is placed from you the less attractive it becomes, so to say. So that if you know "oh it's from my neighbors". It just doesn't strike me as pleasant' (Almere Poort, Regular flush toilet).*
- (B) *'I see that [reuse for energy] as more positive, since it is placed further from you. Because then it has nothing to do with your (food) consumption, so that would be ok I guess' (Almere Poort, Regular flush toilet).*

Table 1. Typology highlighting the most important neighborhood characteristics^a.

	Almere Poort (N = 28)	Buiksloterham (N = 9)	Almere Oosterwold (N = 54)
Total approximate number of households	6.500	46	Early construction phase, planned 15.000 houses.
Total area in km ^b	8.6 km ^b	< 1 km ^b	43 km ^b
Type of housing	Mixed low and high density	Low density (floating homes)	Low density
Type of toilet	Regular flush toilet (93%), Don't know (7%)	Vacuum toilet (100%)	Regular flush toilet (84%), Composting toilet (7%), Separation toilet (2%), Other ^b (7%)
Sewage connection	Regular connection	Separated blackwater	Onsite sewage facility
Circular orientation	None	Waste-to-energy	Waste-to-food
Willingness to give up on comfort and/or ease of use for reusability of wastewater	Very low	Medium/High	Medium
Attitude towards reusing wastewater for energy	Very positive	Very positive	Positive
Attitude towards reusing composted human waste for food production	Neutral	Very positive	Neutral
Willingness to use composted human waste in one's own garden	Low	Medium	Medium
Attitude towards consumption of food grown on composted human waste	Negative	Neutral/Positive	Neutral
Attitude towards to composting human waste collectively	Negative	Neutral/Positive	Neutral

^aUneven inclusion of respondents can be attributed to differences in the total number of households per neighborhood. Due to low sample sizes, results should not be used quantitatively.

^bFor example Japanese shower toilets.

The 'distance to user' also goes for food safety and specifically relates to (perceived) risks that are beyond our control. Even though people might be open to the idea of reusing human waste for food production, they dislike using the excrements of others than one's own family not only because it might be repulsive, but also because of the abundant use of pharmaceuticals in today's society and the persistence of these substances in the environment – even when human waste has gone through a composting process:

"I am really positive to the reuse of excrements, just not those of other people. With the current use of medicine I would never use compost from people other than my own family, not even for non-edible plants because it still ends up in the soil" (From email contact, Oosterwold).

This perception of risk in reusing human waste is exacerbated by images of trust. Namely, although people might trust their closest kin, they cannot control the behavior of others. So, whereas they might be willing to use their own feces for compost because they have knowledge about what goes in – i.e. whether their excrements might contain pharmaceuticals – they can't say the same for their neighbors'. Therefore, collective waste-to-food solutions are further compromised by issues regarding trust:

"If you have a collective system you could say yeah you need to trust each other but forget about that. Because there is no trust. [referring to food production and agro-chemical use as an example:] people also find that you shouldn't use agro-chemicals, but as soon as they have weeds they'll resort to using poison. [...] So with collective sewage exactly the same logics apply." (Oosterwold, Japanese shower toilet).

5. Discussion

The previous sections highlighted how we have grown accustomed to specific behavioral routines regarding the use of household sanitation, and what this may imply for the utilization of resource-oriented sanitation in circular systems. This focal point is particularly relevant in the debate around the sustainability of food systems, where issues such as soil erosion and resource depletion in agriculture are putting increasing stress on the security of future food stability (Alewell et al. 2020; Cordell and White 2015). The production of chemical fertilizers is still reliant on the continued mining for phosphate rocks and other nutrients, while in the meantime these finite resources are gradually being lost to surface waters due to the way sanitation systems are organized (Smit, Bindraban, Schröder, Conijn, & Meer, 2009). Efforts are already being made in (inter) national policy to rethink food systems and close the loops, like the EU's 'Farm to Fork Strategy' listed in the European Green Deal or the push for 'Kringlooplanbouw' (Circular Agriculture) in the Netherlands. However, with some exceptions (Hegger et al, 2007; Van Vliet et al, 2010) the role of sanitation at the household level is often overlooked within these discussions – when in fact household wastewater contains many of the resources needed for fertilization (Van der Kooij et al., 2020; Haq & Cambridge, 2012).

A double loss is thus occurring. Resources are first lost through processes of soil erosion and runoff in agriculture, and second, resources that do remain in wastewater fail to be sufficiently recovered for circular purposes. While wastewater products can also be used for purposes of energy production, the role of sanitation in food systems might even be more important

considering issues of resource depletion affecting agriculture. It is consequently key to understand the embeddedness of sanitation practices, as this determines the way in which people may come to make use of resource recovery oriented sanitation infrastructures.

However, our current habituated sanitation practices have evolved into prioritizing cleanliness and maintaining hygiene in a convenient manner. The development of mainstream sewage infrastructure and wastewater treatment has – besides a technological lock-in comprising a network of sewage pipes and treatment plants – also locked in specific socio-cultural norms and beliefs around hygiene and cleanliness into our sanitary routines. This translates itself into emphasis on freshness and ‘empty’ bowls, and stimulating abundant use of chemical toilet cleaners and brushes. Due to this intricate link to the meaning of hygiene, the practice of saving water might even lead to increased use of chemical toilet cleaners to compensate for any possible stains, as we have been cultured to disprove its presence. Elements of sanitation practices continuously co-shape each other as such belief structures and learned conventions are again echoed into the materialization of sanitary design: preferably shiny, white, hanging and abundantly flushing.

Within circular sanitation-food systems, sanitation practices also become enveloped by bundled practices concerning the production of food. Zooming out on these bundles enables capturing the wider ‘*texture of dependencies and references*’ (Nicolini 2009, 22) in which sanitation practices become situated, and where certain bundled belief structures determine the way in which sanitation practices are performed. As illustrated, the sanitation-food connection results in specific normative evaluations on food safety, health risks and ‘bringing back the senses’; concerns that are even further amplified by collective ways of reuse. Reusing wastewater for food production would thus require opening up the socio-cultural norms and practices associated with current forms of sanitation.

It is this kind of embeddedness that stresses the need for circular developments in sanitation to explicitly recognize the social practice side of such a transition, not just the infrastructural provisions. The use of resource-oriented sanitation in circular systems has a much better chance of becoming normalized when it reiterates the notions and beliefs that are deeply ingrained into our lifestyles and bundled practices. A shift in normative orientation is thus crucial; constituted goals from the past concerning the upkeep of household cleanliness and hygiene need to be substituted by goal-oriented norms with regard to sustainability and circularity. The historically grown mundane practice components must be *de-routinized* to enable the normalization of resource-oriented sanitation

practices. This means that we need to have eyes for the steppingstones behind de-routinizing mundane and normalizing novel sanitation practices.

Since sanitation is often overlooked within circular policy, we have, based on the performance and embeddedness of sanitation practices, identified five steppingstones that could be used to support the role of sanitation practices in circular food and sanitation discourse. These steppingstones help in understanding how normalization of novel sanitation practices can be achieved by drawing attention to the de- and re-routinization processes required in individual practice components, and center around a shift in normative orientation from cleanliness to sustainability:

- (1) *Experience with resource-oriented sanitation:* Already having prior (positive) experience with alternative sanitation systems could help to decrease or even get rid of the de-routinizing shift that comes with novel sanitation practices.
- (2) *Knowledge of novel sanitation practices:* If people know that their sanitation can benefit the environment and also know how to do this, the shift to novel sanitation practices becomes easier. Additionally, clarity of information on resource-oriented sanitation should be available and accessible to prevent dispute.
- (3) *Design of the toilet:* Emphasis on the cleanliness and convenient hygiene of circular toilet systems reassures citizens of the normality of novel sanitation practices.
- (4) *Consideration of the micro-meso-macro level of reuse:* The level at which novel sanitation practices are performed has an ambiguous effect on normalization. At micro-level, where reuse is solely performed by a single household, the purpose for reuse (e.g. vegetable garden) is known and risks are manageable. Here, likelihood of normalization is relatively high. At macro-level, where reuse is performed collectively and its purpose is more ‘distant’ (e.g. large-scale agriculture or energy production), likelihood of normalization is also relatively high. However, at meso-level, when reuse is performed collectively but its purpose is local (e.g. urban agriculture), normalization is less likely to occur as risks are both easily perceptible but also relatively harder to manage.
- (5) *Weighing of environmental engagement with subjectivity of smell, vulgarity and (convenient) hygiene:* If people are truly committed to improving the environment, their positive impact on the environment might eventually outweigh the discomfort that comes with the required novel sanitation practices.

6. Conclusion

Wastewater contains a number of resources that can be utilized by incorporating sanitation in energy and food systems, but the value of such infrastructural connections is often left unnoticed in circular trajectories. Especially when transitioning food systems towards circularity, it is imperative to acknowledge the role household sanitation could play in assuring the long-term viability of food systems. In transitioning sanitation to become part of food systems, it is likewise pivotal to uncover the embedded nature and inconspicuousness of sanitation practices as the intimate web of belief structures and ideas that made up these practices. The focus of this paper was therefore to uncover de- and re-routinizing pathways to novel sanitation practices.

Based on the distinctive features of the sanitation infrastructure in our case study neighborhoods, our paper demonstrates how sanitation practices are varying not only between, but also within neighborhoods. This emphasizes the importance of understanding sanitation practices at the household level, including and going beyond physical infrastructures. The primary reason for the observed variation can be attributed to the embeddedness of toilet routines within specific lifestyles and bundled practices. This partly explains the varying willingness to engage in resource-oriented sanitation systems. Though, it was also observed how specific neighborhood sanitation infrastructure provided some citizens the opportunity to harmonize their sanitation and environmental meanings. Meanwhile, engagement with resource-oriented sanitation itself also resulted in citizens having to construct new competences and materials, while ideas and normative orientations around hygiene shifted. Environmental meanings do matter in the acceptance of such inconveniences, but to normalize novel sanitation practices, policymakers' attention should also be paid to the competences and materials involved – simultaneously shifting goal-oriented norms of cleanliness towards sustainability.

Note

1. All research subjects have given their written consent for sharing their details to researchers and for anonymized publication. Ethical clearance to this research was granted by the Social Sciences Ethical Committee at Wageningen University & Research dd. 27 January 2022.
2. Ironically, this cognitive pattern is not entirely correct. Yes, the smell of bleach might invoke a feeling of hygiene, but if the criterium for a 'clean' toilet is the removal of stains and dirt, then bleach fails to do so effectively. Yet, the interviewee is convinced that cleaning using bleach is the best way of maintaining sanitary hygiene.

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