



Research Paper

Personal communication as a strategy to improve the quality of household organic waste – Does it work? results from a quasi-experimental study in Northern Hesse, Germany

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ABSTRACT

Household organic waste has great potential for closing nutrient cycles in agriculture. This requires proper waste separation by households. Personal communication at the doorstep potentially improves household waste separation behaviour but it is expensive and findings from existing research are mixed. Based on results of previous studies and from a quasi-experiment with non-equivalent groups design in two German municipalities, this paper argues that efficiency of personal communication depends on its context. It can positively influence behaviour when recycling is voluntary and participation rates are low. However, it has no significant effects if recycling is mandatory. One explanation could be different perceptions of recycling in mandatory and voluntary schemes. In voluntary schemes door stepping can activate the intrinsic motivation of households. In mandatory schemes, all households need to participate irrespective of intrinsic motivation. This research shows that this creates a situation in which a small share of households is responsible for almost all contamination. This can be overcome by considering extrinsic factors that affect recycling behaviour. The paper recommends further research to understand which combination of incentives, sanctions and information is efficient in affecting behaviour change in mandatory recycling schemes.

1. Introduction

Organic waste collected from households is a valuable resource for recycling (Clark, 2017). One potential utilisation is the production of compost as input for agriculture. Compost has positive impacts on nutrient supply, carbon sequestration, erosion and several other parameters of soil (Martínez-Blanco et al., 2013). Compost produced from household organic waste is even more beneficial to close nutrient cycles as the contained nutrients are more plant available than in other kinds of compost (Paes et al., 2019). Therefore, proper recycling of organic waste allows to close nutrient cycles and to alleviate negative nutrient balances. These are particularly prevalent among organic farms without livestock where on-farm nutrient cycles are constricted and need to be extended towards regional nutrient cycles (Foissy et al., 2013). Besides this, organic waste can also be used as input for biogas plants and thus contribute to providing energy and heat to households (Meyer-

Kohlstock et al., 2013). In that way, organic waste recycling can have further positive environmental effects such as mitigating climate change, minimize resource depletion or reduce landfill.

However, to use that potential, correct waste separation at source, i. e. at the household level is crucial. Technical treatment of waste after collection from households can filter out incorrectly sorted waste. Yet, this process is expensive and cannot filter out all miss-sorted materials (Doumet & Thärichen, 2021). This means that there is no alternative to ensuring proper waste sorting by households.

This paper presents the results from a quasi-experimental study with non-equivalent groups design that aimed to investigate the effectiveness of door stepping as a strategy to reduce miss sorting of non-organic waste into organic waste at the household level. Door stepping was chosen as a strategy because it offers high potential for behavioural change (Dai et al., 2015; Green, 2019; Karkanas et al., 2016). However, there remains disagreement in the literature regarding its effectiveness

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for influencing household recycling behaviour. Some studies report positive effects while others find no or insignificant effects (Sewak et al., 2021). Considering that door stepping is one of the most cost intensive strategies to influence household recycling behaviour (A. Read, 1999), clarifying its effectiveness for reducing miss sorting is a relevant topic for research.

Based on the results from the quasi-experimental study and a review of existing literature, this paper argues that the effectiveness of door stepping is strongly dependent on the context in which it is used and the goal of the intervention. Door stepping seems to be an appropriate method in conditions where recycling is voluntary or not well established and the goal is to increase participation rates in recycling schemes. However, it seems to have no or insignificant effects in contexts where recycling is mandatory and the goal is to improve the quality of organic waste.

In the next part, the paper reviews existing research on door stepping with a focus on how and under which circumstances door stepping was used. Insights from this literature review informed the design of the study presented in this paper. The third part introduces the research presented in this paper and the data collection and analysis tools used. After that, findings are presented and discussed in context with results from previous research. The final part draws conclusions and gives recommendations for practitioners and further research.

2. Door stepping to improve recycling behaviour

Several factors influence household recycling behaviour, including structural factors such as accessibility of local collection facilities (Bernstad, 2014; Stoeva & Alriksson, 2017; Zhang et al., 2016), collection method (Best & Kneip, 2019; Martinho et al., 2017; Matsumoto, 2011), convenience (Abbott et al., 2017; DiGiacomo et al., 2018) and individual factors such as knowledge, personal norms and attitudes (Arain et al., 2020; Barr, 2007; Latif et al., 2012; Schill & Shaw, 2016; Vicente & Reis, 2008). Norms can also play a role on the societal level when recycling behaviour is influenced by how people assume to be seen by others, creating peer pressure to participate in recycling (Abbott et al., 2013). Norms and attitudes are in turn influenced by whether recycling is voluntary or mandatory. Research suggests that in mandatory recycling schemes, recycling is perceived as a legal obligation whereas environmental values and social norms are more important in voluntary schemes (Smeesters et al., 2003). One widely used strategy to influence individual factors of recycling behaviour is door stepping (Sewak et al., 2021). The idea behind door stepping is that personal communication can engage people with a certain issue and change their behaviour by influencing their knowledge and attitudes towards that issue (Green, 2019). At the same time, pro-environmental knowledge, norms and attitudes do not always lead towards pro-environmental behaviour (Quimby & Angelique, 2011).

In a literature review of earlier studies on door stepping and recycling behaviour, Porter et al. (1995) reported that verbal communication is more effective in improving recycling behaviour than textual communication. Studies in the review looked at recycling behaviour based on participation rates and the amount of waste collected. A number of studies have followed-up on the impacts of door stepping on recycling outcomes. Conclusions from these studies were inconclusive:

Read (1999) reported that door stepping increased the amount of recycling material collected. He attributed this change to the impact of door stepping on changing the habits of study participants with regard to recycling. Another impact was improvement of knowledge about recycling services. 73 % of households that did not participate in recycling stated that their non-participation was due to missing knowledge on the existence of the scheme. The study analysed the effects of a roadshow in which a roadshow team visited households in two London boroughs to inform people about benefits of recycling and answer their questions. The observed interventions took place in areas with low initial recycling participation rates and improvements in recycling participation were

higher in areas where initial participation rates were lowest. According to Cotterill et al. (2009), door stepping has a moderate positive impact on participation rates in curbside collection, albeit with a limited long term effect. The effect was stronger in areas with lower recycling rates at the baseline. Recycling participation rates were measured by bin-set out rates of visited households compared to those of households in a control group in North West England. In the study, door stepping was used to raise awareness and attitudes among participants and to reduce structural barriers by distributing adequate plastic bags for recycling. This means that the measured effects might have been influenced by reducing structural barriers through plastic bag distribution rather than the individual level effects of door stepping as such.

Dai et al. (2015) also found a positive influence of door stepping on recycling behaviour, measured as an increase in collected residential food waste. They attributed this effect to social norms that were emphasized through door stepping and to door stepping functioning as a prompt. Other effects of door stepping such as improving participants' knowledge, skills, belief of consequences, motivation or understanding of consequences were found to be insignificant for changing participants' behaviour. However, their study took place in apartment blocks in Shanghai, a city in which a food waste recycling pilot scheme has been introduced in 2011, four years before the study. The importance of framing recycling as a social norm for the success of interventions is underlined in a literature review by Knickmeyer (2020) that looked at 166 peer-reviewed papers and other documents published after 1999, mostly from Europe and North America. The review stresses the importance of social norms to establish a "recycling culture". Further important factors identified include external factors such as recycling infrastructure to make recycling convenient for participants. According to Huang et al. (2018), door stepping has a positive impact on recycling rates and contamination levels if the message is delivered with a positive attitude. They did not find an impact if personal messages are delivered in a neutral tone. Their study was also conducted in apartment buildings in Shanghai, thus in a context similar to the study of Dai et al. (2015).

Scott and Tavri (2018) reported that door stepping led to an increase in recycling rates in their intervention area in a London borough. The door stepping campaign specifically targeted areas with low participation rates in the borough. Success was measured by monitoring before and after set out rates of recycling bins. However, the door stepping campaign was connected to an announcement of financial penalties for non-recyclers. It is therefore not clear if the increase in recycling rates can be attributed to the effects of the door stepping, to the announcement of a penalty or to a combination of both. Willman (2015) conducted an experiment in Fairfield, Ohio in which he found that personal delivery of information leaflets had a significant impact on the decision of people to adopt larger recycling bins. The adoption of the larger bins was voluntary. The study does not report on subsequent use of the larger containers. Furthermore, the study underlines that the intervention did not increase the number of households that participated in the recycling scheme. Read et al. (2009) reported a positive impact of door stepping on behaviour change regarding waste prevention in their intervention area in Dorset County, UK. Results were attributed to changing attitudes because of the campaign. However, the results indicate that the intervention did not have a long-term effect. The campaign impacts were measured as the weight of household waste collected at the curbside. The examined door stepping campaign took place in selected areas of the intervention area. Campaigners visited households once during the campaign and offered information on waste prevention, reusable jute bags and the offer to subscribe to a mailing newsletter.

These results confirm the general potential of door stepping to impact individual recycling behaviour through raising awareness, changing attitudes and creating new habits. However, all studies (with the exception of Scott and Tavri (2018)) were conducted in environments where recycling was voluntary or not well established at the time of research. Therefore, the findings cannot necessarily be translated to contexts with mandatory recycling schemes or high participation rates

at baseline. Furthermore, the studies (with the exception of Dai (2015)) measured the effects of door stepping on recycling participation rates or the amount of waste collected but did not look at its effects on improving waste separation behaviour.

In contrast to these promising results, a number of studies have found no or statistically insignificant impacts of door stepping. Timlett and Williams (2008) analysed door stepping as a strategy to increase recycling participation and reduce contamination rates in Portsmouth, England. They used door stepping to deliver information about recycling and to convince people to participate. They have not found significant impacts of door stepping on recycling participation rates or quality of the collected material. However, they cautioned that participation rates in the study area had already been high before the intervention. Similar conclusions were drawn in a study conducted by Bernstad et al. (2013) in a residential area in Malmö, Sweden. The campaigners visited households once during the campaign and informed citizens on the environmental benefits and importance of correct waste separation and delivered a specialized vessel and paper bags for waste collection. They observed a decrease in contamination after door stepping, which was however not statistically significant and did not show long-term effects. The study was conducted in an in Sweden, where source-separation of waste by households has been mandatory for several years. Alexander et al., (2009) also did not observe significant effects of door stepping in terms of increasing recycling rates and reducing contamination in a study conducted in London and Portsmouth, UK. Similar to other studies in which no significant effects are reported, participation rates in recycling had been high in their intervention area prior to the intervention. Due to the high costs related to door stepping, they do not recommend it as effective strategy for mass communication.

The literature review shows that there is no unanimity among scholars whether door stepping has effects on individual level recycling behaviour. Most of the studies reviewed discuss door stepping in regard to how the intervention was planned, i. e. which kind of information was given, whether it served as a prompt, to change attitudes towards recycling or for the provision of information. Less attention has been given to the circumstances under which door stepping might be effective, that is if recycling is voluntary or mandatory, newly introduced or a well-established practice. However, since this has an impact on the norms and attitudes towards recycling (Smeesters et al., 2003), this is a crucial point in the discussion.

Studies that report a positive impact of door stepping looked at participation rates in recycling schemes and at the amount of recycled materials. They investigated the impacts of recycling in settings where participation in such schemes was voluntary or where recycling participation rates were low before the intervention. This might explain why door stepping can improve recycling rates through influencing social norms as reported by Dai et al. (2015) or serve as a prompt as suggested by Porter et al. (1995). However, it appears that these findings cannot be translated into settings where recycling is mandatory and/or well-established. Studies that could not find a significant effect of door stepping were conducted in settings where recycling was well established with high participation rates even before the door stepping campaigns. In these settings, studies also did not report significant impacts on contamination rates. This implies that the effects of door stepping depend on the circumstances in which it is used. This could be caused by the fact that participants of mandatory schemes do not see recycling as a social norm but a legal requirement so that the mechanisms that work in successful door stepping campaigns do not work. To clarify this, the authors of this paper conducted a quasi-experimental study that analysed the effects of door stepping on contamination rates, supported by a survey that investigated participants' perceptions of recycling and the door stepping campaign in a mandatory recycling scheme.

3. Methodology

3.1. Experimental setup

The study has been conducted in the Werra-Meißner region in Germany where recycling has already been mandatory by municipal laws for several decades (Kreisstadt Eschwege, 2013). Thus, separation of organic waste into separate bins is a well-established practice in the study area. Yet, based on information from the local authorities, it is known that miss sorting of plastic, glass, metal and other substances is significantly higher than in the German average and higher than contamination thresholds set in the German recycling laws. The laws specify that the contamination rate of organic waste delivered to compost plants must not exceed one mass percent. If the contamination rates exceed three percent, compost plants are allowed to refuse the treatment of the delivered organic waste (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, 2022).

The research was designed as a quasi-experimental study with non-equivalent groups design in the two small towns Witzenhausen (15.000 inhabitants) and Eschwege (20.000 inhabitants) in the German Northern Hesse region. Households are required to separate their organic waste into specified green bins. Exemptions are possible if households can prove that they have their own compost facility on their property. All bins are emptied through regular curbside collections. This means that collection method and convenience as two of the most important influential factors on recycling behaviour (Sewak et al., 2021) have no impact on the study results.

As a general intervention, articles in the local newspapers informed about the issue of high miss-sorting levels in the area and gave information on how to separate waste correctly. Furthermore, the regional public broadcaster sent a television report with similar content. In both municipalities, one group received only the general information from the local press with no further personalized measures. Another group received additional information through leaflets distributed to their letterboxes. Leaflets contained information on the importance of organic waste as an input for compost production and for biogas plants. The leaflet also contained QR-codes with links to the information in different languages (English, Arabic, Turkish and Russian) to overcome possible language barriers. As it is known that information distribution increases participation in recycling (Vicente & Reis, 2008), this was assumed to also be relevant for reducing contamination rates. Furthermore, messages relating to personal benefits are found to be more effective for individual behaviour change (Timlett & Williams, 2008). Leaflets were therefore designed to give people information on which substances were allowed in the organic waste and which had to be sorted into residual waste. Information also aimed at raising awareness of the social and environmental costs of miss sorting and the benefits of well-sorted organic waste for compost production and its positive environmental effects. The goal was to raise people's awareness of being part of a larger chain and their crucial position therein. This aimed to present waste separation as social norm, as suggested by Dai et al. (2015). The third group received the leaflets in combination with personal communication in a door stepping campaign. During the campaign, one campaigner who identified themselves as representatives of the local authorities personally visited the households. In a first step, the campaigner asked for the households' consent for a three to five minute conversation on the importance of organic waste as a resource and the preeminent role of households in compost production. They justified their visit with the necessity to reduce miss sorting rates as these exceeded national average rates and the rates allowed by German recycling laws. In the following personal communication, the campaigners emphasized the information given in the leaflets and answered questions of participants. The door stepping took place in the afternoon between five and seven o'clock to make sure that most people would be at home. If campaigners did not reach a household in the first attempt, they visited two more times. If

they could not reach a household in three attempts, they left the information leaflet in the letterbox to ensure that every member of the door stepping group would receive at least more information than members in the general information group. 68 % of households in the door-stepping group were personally contacted in Eschwege. In Witzenhausen, this rate was 90 %. In the overwhelming majority of cases in which personal contact was not possible this was due to non-response. In only a handful of cases households rejected their consent for personal communication.

In both municipalities combined, 200 households only received general information via the media, 200 households received additional leaflets and 200 households were selected for door stepping. All information was distributed right after the last curbside collection to rule out the possibility that miss-sorted materials would have been in the bins from before the treatments.

3.2. Sample selection

For the study, three groups of 100 households were selected in each of the two municipalities, i.e. overall, 600 households were included. Households were selected to be in the same or adjoining streets so that separate collection of bins by experimental group for a waste sorting analysis was manageable for the local waste management authorities. This approach was also chosen to make sure that neighbours received the same treatment to avoid confusion about different information campaigns running in the same neighbourhood. It is known from experience of the local waste management authorities and from other studies (Yau, 2010) that dwelling type influences recycling behaviour. Therefore, the groups were chosen to include single and multi-party houses in similar proportions.

3.3. Waste sorting analysis

Previous studies have found that recycling behaviour in surveys is frequently over reported (Scott & Tavri, 2018; Thomas & Sharp, 2013). Therefore, the impact of the interventions was measured through a waste sorting analysis. On collection day, the organic waste of the selected households was collected separately from that of non-selected households for each experimental group for a waste sorting analysis. The waste sorting analysis followed the procedure as prescribed by the *Bundesgütegemeinschaft Kompost* (German Federal Compost Association) (Bundesgütegemeinschaft Kompost, 2017). For each group, two compost samples of 250 kg were selected. To that end, the organic waste was evenly spread on the ground with the help of a wheel-loader and further separated into eight smaller chunks by hand. Half of these chunks were selected for the waste sorting analysis. The same procedure was used to generate the second sample. The two samples were sorted and categorized into seven categories on a sorting table:

- organic waste.
- plastic.
- packaged food.
- metal.
- glass.
- hazardous waste.
- other residual waste.

Through weighing of the materials in each category, the share of miss sorted materials in each sample was determined with the formula: $\frac{\text{Weight of miss sorted materials} \times 100}{\text{Sample weight}}$. Afterwards, the average share of miss-sorted material in both samples was calculated to determine the overall amount of miss sorted materials per experimental group.

A municipality-wide waste sorting analysis was conducted in both municipalities before the start of the experiment, using the same procedure. This data was used as indicator for pre-treatment contamination

rates. Even though this does not give pre-treatment contamination rates per group, it was assumed that if door stepping has an effect that is proportional to its high costs, the contamination rates in the door-stepping groups should be lower than the pre-treatment municipal averages. Furthermore, the effect should be observable in the door stepping groups in both municipalities.

3.4. Visual inspections

The waste sorting analysis was followed up with visual inspections of the organic waste bins at the collection day after the one at which the waste sorting analysis took place. While a waste sorting analysis allows to determine the overall share of miss sorted materials in an area, visual inspections allow a household-wise detection of miss sorted materials (Kern et al., 2023). The analysis of the visual inspection followed a 5-point rating scheme by Kern (2017) as outlined in Table 1. Fig. 1 shows samples of waste bins and their respective ratings. Similar photos were taken for all waste bins of the respective households and categorized according to the five-point rating scheme. Afterwards, the share of waste bins in each category was calculated for each experimental group for comparison.

3.5. Household survey

Next to the waste sorting analysis, a household survey was conducted to evaluate participants' perceptions of the measures and to prop up the data from the waste sorting analysis. To get an overview of the participants' perception of the information campaign, the questionnaire asked how often participants had perceived information on waste sorting in the previous six months. If participants stated that they had perceived information, the questionnaire asked about the source of the information (magazines, internet, leaflets, etc.) to determine whether the perceived information came from the campaigning or was picked up from a source not related to the experiment. Further questions asked about participants' recycling knowledge and perceived usefulness of the information for influencing recycling behaviour. To measure the perceived usefulness of the information, the questionnaire used five-point Likert-scales with five statements such as "The information I received helped me to better understand which waste needs to be separated into which waste bin" (original questionnaire in German, translation by the authors). Further questions included Likert-scales measuring the general attitude towards recycling through five statements such as "Recycling is first and foremost a legal obligation". These statements aimed to measure in how far participants saw recycling as a social norm, which was identified as an important factor to influence recycling behaviour in earlier studies (Dai et al., 2015; Knickmeyer, 2020). The statements only looked at explicit attitudes which means there is some room for social desirability bias. However, a meta-analysis of social desirability bias in environmental issues by Vesely and Klöckner (2020) showed that effects are generally small so that it was assumed that reported answers would correlate with actual attitudes.

The household survey was conducted as in-person standardized interview. Similar to the door stepping campaign, interviewers visited the households up to three times to record their answers at the door step.

Table 1
Rating scheme for visual inspections following Kern et al. (2017).

Classification	Characterization
A (1)	No contamination visible
B (2)	Only one (uncritical) contaminant visible
C (3)	Two to three uncritical contaminations (flowerpots, packaged foods, lightweight packaging)
D (4)	Several contaminations visible but (no critical ones*), organic waste and contaminations are in balance
E (5)	Contamination clearly dominates or critical contaminations visible

* critical contaminations are glass, hazardous waste, electronic scrap.



Fig. 1. Examples of waste bins rated 1 (no miss sorting), 3 (some miss sorting) and 5 (miss sorting dominates) respectively.

This method was chosen because previous studies reported that mail distribution of questionnaires resulted in low response rates, possibly leading to non-response bias (Bernstad et al., 2013). Face-to-Face interviews consistently lead to higher response rates (Schröder, 2016). Interviewer effects were held at a minimum by using standardized questionnaires and interviewers unknown to the interviewees. Answers were recorded through digital devices to avoid errors from digitalizing paper–pencil questionnaires.

4. Findings

4.1. Waste sorting analysis

The waste sorting analysis for the pre-treatment average was conducted in January 2022 while the analysis of the post-treatment groups took place two months later in March 2022. The information, including the door-stepping campaign, were distributed in February. Gardening activities in springtime lead to a dilution of contamination rates because organic waste from gardens is less prone to miss-sorting through plastic, packaged food and other categories than kitchen organic waste. The post-treatment data were therefore corrected for this difference by

adjusting the share of organic substance from gardens to the levels of January.

The results from the waste sorting analysis show that the groups that were personally visited through door stepping showed the highest contamination rates. This was the case both in Witzenhausen and in Eschwege. In Eschwege, contamination in the door stepping group was only marginally lower than the municipal average. In Witzenhausen, the contamination rate in that group was more than twice as high than in the pre-treatment municipal average. The lowest contamination rate in Eschwege was in the group that received information only via the media, in Witzenhausen the lowest rates are in the group that received additional leaflets (Fig. 2).

4.2. Visual inspections

The results of the visual inspections show that the highest share of critically contaminated waste bins was in the leaflet group in Eschwege, followed by the general information group in Witzenhausen (Fig. 3). The lowest share of contaminated bins was in the door stepping group in Eschwege. The door stepping group in Witzenhausen showed only marginally better contamination rates than the control group. There is

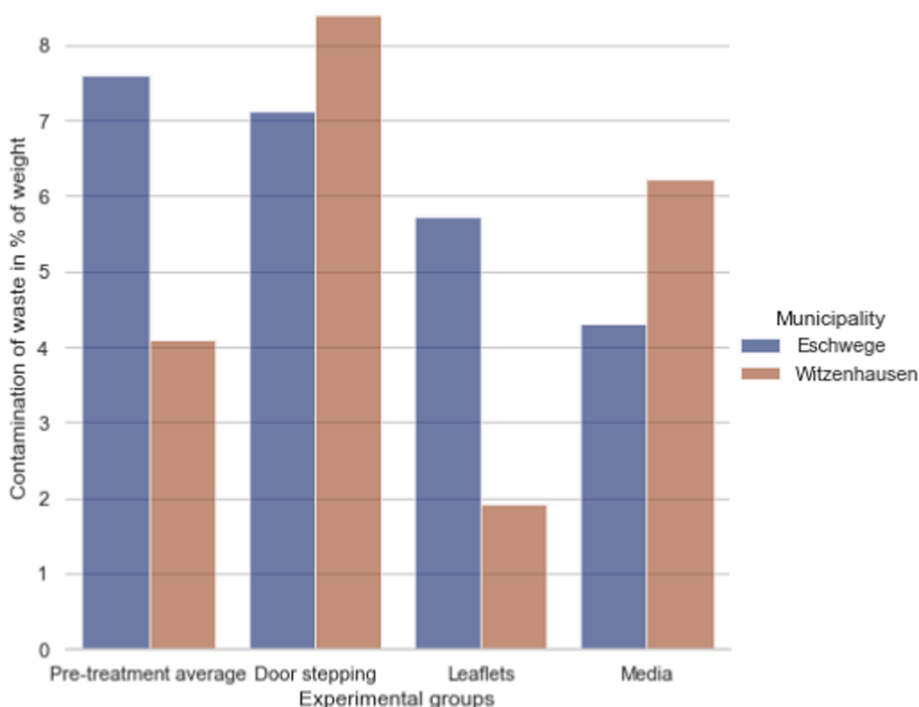


Fig. 2. Contamination rates by treatment group.

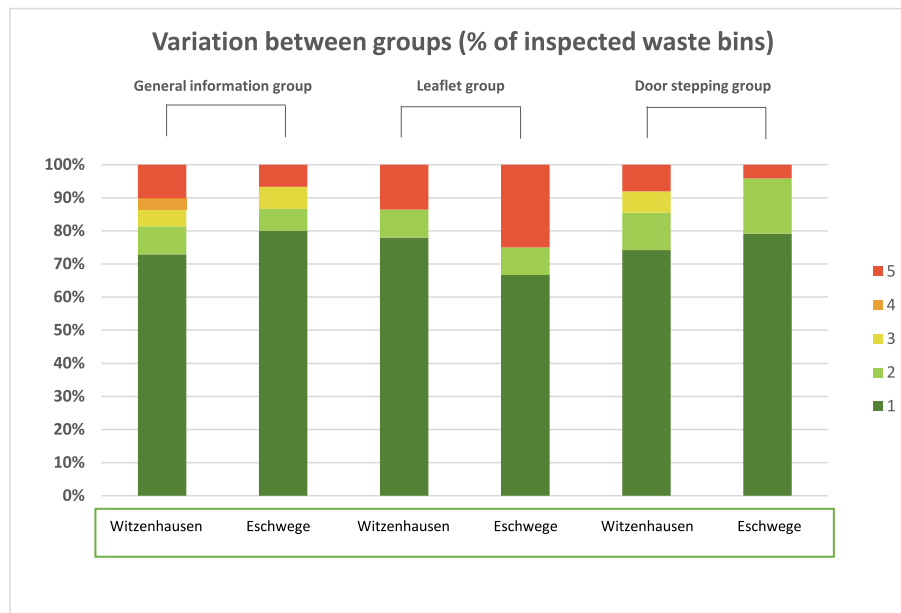


Fig. 3. Percentage of waste bins classified into each category by group and municipality.

no clear connection between the share of contaminated bins and the information measures. Overall, it is notable that few bins fall into the categories three and four while the overwhelming majority of bins was either well sorted or significantly contaminated.

4.3. Household survey

The survey yielded a response of 295 questionnaires, which is a response rate of 49.1 %. Survey non-response was due to participants who declined to take part in the survey or who could not be reached at home after three visits. The survey was conducted four months after the door-stepping in order to see whether participants memory of the information campaign was higher in that group.

In a first step, the analysis looked at differences in participants awareness of the information campaign, i. e. participants reports of how often they remembered to have perceived information regarding organic waste separation in the last six months. The numbers (Fig. 4) show that the door stepping group has the highest number of participants who report to have received information regarding waste separation more than once. Compared to that, the highest number of participants who reported to have received no information is in the general information group. However, a Chi-Square test of independence showed that ($n = 295, \chi^2: 60.67, p > .05, df = 6$) the differences between groups are not

statistically significant. This indicates that door stepping might not be effective to boost the impact of other information carriers by raising general awareness for the info campaign.

To analyse whether participants in the door stepping group perceived the information as more useful to influence their recycling behaviour than the participants in the other experimental groups, a “perceived information usefulness score” was created out of the Likert-scales values. As the score was constructed out of a five-point Likert scale with five items, the minimum score was 5 and the maximum score 25. The analysis only included participants that said they remembered to have perceived information about organic waste separation at least once in the previous six months. The mean scores between the groups were analysed with a one-way ANOVA. Before conducting the ANOVA, Levenés test for equality of variance was found to be significant ($p > .05$), indicating homogeneity of variance. The one-way ANOVA did not show significant differences ($F(2, 177) = 10.69, p > .05$) in mean score values between the groups (Fig. 5). The results were confirmed by a Kruskal-Wallis test ($H(2) = 40.53, p > .05$).

As it is known that the dwelling type influences recycling behaviour, a second analysis looked at whether participants that shared their waste bins with no or one other household perceived the information differently from households that shared their waste bins with two or more other households (Fig. 6). A one-way ANOVA did not show significant

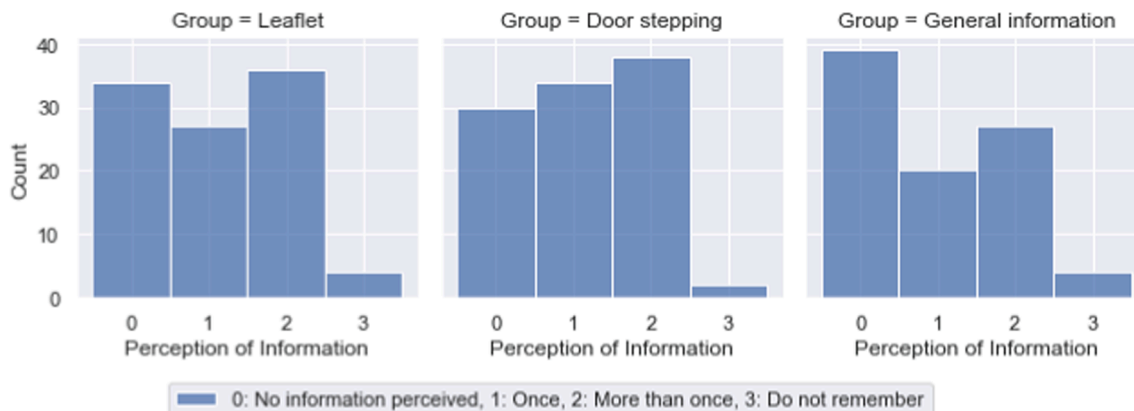


Fig. 4. Perception of information campaign by group.

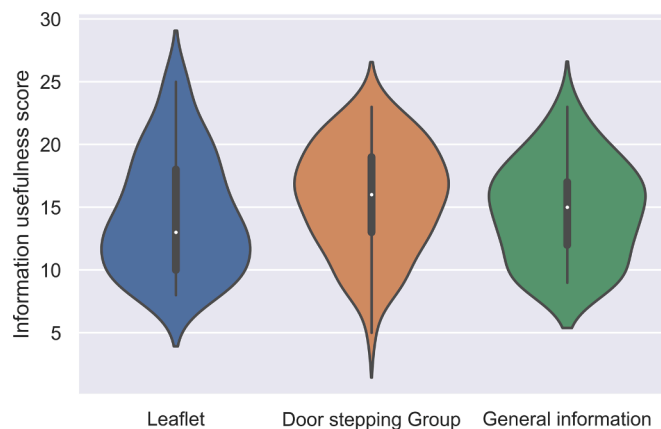


Fig. 5. Perception of information usefulness per group.

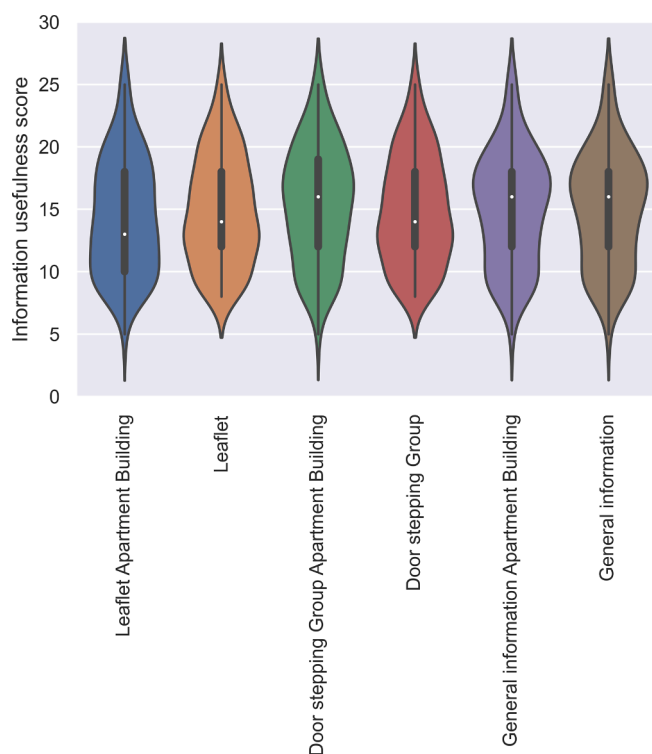


Fig. 6. Perception of information usefulness per group and dwelling type.

differences ($F(2, 177) = 0.5, p > .05$). Results from a non-parametric Kruskal-Wallis test confirmed the ANOVA results ($H(2) = 20.75, p > .05$).

Finally, the analysis looked at the perception of recycling, i. e. whether participants regarded participation in recycling as a desirable social norm or rather as a legal requirement. The analysis used a three-item Likert scale to generate an “attitude scale” similar to the “perceived information usefulness score” in the previous analysis. Fig. 7 shows the score values for the different groups in a transformed form where a higher score indicates that participants regard waste separation as a societal norm rather than a legal obligation. Results show that the majority of participants obtained moderate score values, indicating a mixed attitude towards recycling behaviour. The distribution of scores is comparable among all groups. A Kruskal-Wallis ($H(2) = 0.18, p > 0.05$) test showed no significant differences between group scores.

5. Discussion

The results of the quasi-experiment indicate that door stepping is not an effective strategy to improve citizens’ sorting behaviour of organic wastes if recycling is mandatory. There is no clear relation between the data of the waste sorting analysis, visual inspections and questionnaires and the undertaken measures as one would expect if the strategy had been effective. On the contrary, in both municipalities, the door stepping groups show the highest rates of contamination in the waste sorting analysis. Contamination rates in these groups are even higher than in the groups that only received generalized information via the media. Furthermore, in both municipalities contamination rates in the door stepping groups were not significantly below pre-treatment measurements of contamination rates. In Witzenhausen, contamination rates were even significantly higher than the municipal average used as baseline for comparison. However, if door stepping was an efficient strategy relative to its costs, one should expect the contamination rates in the door stepping groups to be lower than the pre-treatment municipal values, irrespective of group specific pre-treatment contamination rates.

These astonishing results became more explainable when visual inspections of waste bins were carried out. The visual inspections show that the highest share of highly contaminated waste bins was in the leaflet group in Eschwege, followed by the general information group in Witzenhausen. The group with the lowest share of contaminated containers is the door stepping group in Eschwege. However, differences to the leaflet group are only marginal and certainly not proportional to the cost of door stepping. The visual inspections also show that there is only a small share of modestly contaminated bins among all groups. Most bins were perfectly sorted while contaminated bins showed significant amounts of contamination. This finding is supported by data gathered through an automatic detection system on the garbage trucks introduced in Witzenhausen after the end of the field experiment. The data from the detection system show a small number of non-compliant households while the overwhelming majority of households engages in proper waste sorting. The data were not part of the experiment and are thus not shown in the paper. This means that only a small fraction of households in mandatory schemes is responsible for almost all contamination in the overall organic waste. These findings confirm a hypothesis made by Knappe et al. (2019), who however do not present data.

The results of the waste sorting demonstrate that information campaigns are not sufficient to bring contamination rates down to the legally required rates in Germany. Even in the group with the lowest post-treatment contamination rates (two mass percent in the leaflet group in Witzenhausen), rates exceeded the one percent threshold that is required by German recycling laws. All other groups exceed this rate even further so that it appears unlikely that rates could be brought down to required levels even with an intensification of the information campaign.

The survey data support the findings of the waste sorting analysis. Participants in the door stepping group did not show a significantly higher awareness of the information campaign going on than in the other groups, despite the fact that a large majority of households in both municipalities (68 percent in Eschwege and 90 percent in Witzenhausen) had been visited four months prior to the survey. Furthermore, visited households did not perceive the information about organic waste separation as more important to influence their recycling behaviour than those in the other groups; despite the fact that the personal communication allowed participants to ask questions about waste separation to the campaigners, thus allowing for more personalized information. An analysis by dwelling type showed that this did not significantly affect the perception of usefulness of information.

The findings are in line with results by Bernstad (2014), Timlett and Williams (2008) and Alexander et al., (2009) who did not find significant effects of door stepping in similar situations, i.e. in settings where recycling rates are high and thus recycling can be regarded as an

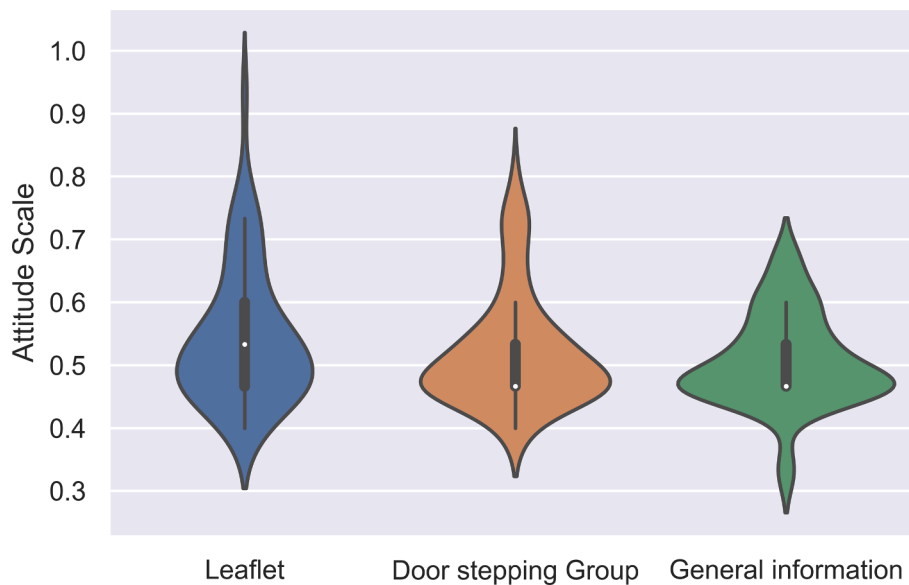


Fig. 7. Attitudes towards waste separation among groups.

established practice.

A possible explanation of the results is that in a setting where recycling is mandatory, there is a share of people who are not intrinsically motivated to recycle but are forced to participate in the scheme. This is indicated by the findings from the visual inspections. It is supported by the results from the survey that found that participants see door stepping partly as norm and partly as a legal obligation. Information about the collective benefits of proper waste separation (costs and environmental benefits) might not be sufficient to convince all non-compliant households to participate, especially those that see no value in proper waste separation. However, in the absence of effective controls, non-compliance with recycling regulations is the cheaper option for non-intrinsically motivated households in terms of time and effort. There is no need to undertake an additional effort to separate waste while there are no costs for non-compliance. At the same time, the environmental benefits of a well-functioning recycling system cannot be withheld from non-compliant households.

On the economic side, all participants share the monetary costs for the recycling scheme, irrespective of their individual recycling behaviour. This creates a free-rider problem (Yau, 2010) which has also been discussed with regard to other pro-environmental behaviours (Quimby & Angelique, 2011). Another possibility is that free riding does not only occur between but also within households as discussed by Jack et al (2018) for the case of water and electricity consumption. This cannot be substantiated by the current experiment but might be an opportunity for future research.

The mandatory scenario is different from a setting in which recycling is optional and campaigns for recycling can frame it as a socially desirable norm. For the latter scenarios, studies have demonstrated a positive effect of door stepping on recycling behaviour (Dai et al., 2015; A. Read, 1999; M. Read et al., 2009). Under such circumstances, door stepping can activate the intrinsic motivation of people while those that do not see the benefits of recycling can decide to be left out of the system altogether. However, activation of intrinsically motivated participants is not sufficient to improve the quality of household organic waste in mandatory schemes. The waste of non-compliant households when bundled with that of compliant households can increase contamination rates to a level at which even a small number of non-compliant households can make a considerable difference in overall contamination levels as demonstrated by the results of the visual inspections.

6. Research limitations

One limitation of the study is the absence of group-specific pre-treatment data. In both municipalities, pre-treatment data rely on the averages for all households. This means that results might be partly attributable to pre-existing differences in contamination rates between the groups. To counter this weakness, the experiment was conducted in two municipalities with independent experimental groups. Furthermore, results from the waste sorting analysis were triangulated with the results from the household survey and the visual inspections.

Another possible limitation is the short duration of the experiment. The interventions were carried out between two collection cycles and all interventions were only executed once. Therefore, possible long-term effects of repeated door stepping campaigns or the other interventions used in the experiments cannot be detected.

7. Conclusion and recommendations

Compost made from household organic waste can help to alleviate negative nutrient balances that are particularly prevalent among organic farms without livestock. For efficient nutrient recycling, organic waste needs to be free from miss-sorted materials. Households therefore play a crucial role in the production of high-quality compost. A potentially effective way to guarantee household participation in recycling is door stepping. However, existing research on the effectiveness of door stepping on recycling behaviour came to inconclusive results. So far, the discussion has not paid attention to the kind of recycling scheme in which door stepping is used. This study looked at the effects of door stepping on recycling behaviour in a setting with mandatory recycling. The results indicate that under this condition, door stepping is not an effective measure to improve household organic waste quality. The hypothesized reason for this is that the badly sorted waste from non-compliant households contaminates organic waste at the municipal level even when the majority of households pays attention to proper waste sorting. In mandatory recycling schemes, non-compliance is the cheapest behaviour for non-intrinsically motivated households in the absence of sanctions. No additional effort for waste separation is necessary as the economic costs and environmental benefits of the recycling scheme are shared with all citizens.

A practical implication of this finding is that policy makers and campaign planners need to pay attention to the specific circumstances and goals of their interventions. If the goal is to increase participation

rates of voluntary recycling schemes, information campaigns including door stepping are a promising method. However, in mandatory schemes where the main concern is the reduction of miss sorting a broader set of measures beyond mere information provision appears to be more promising. These measures should include the identification and sanctioning of non-compliant households. Sanctions increase the costs of non-compliant behaviour and decrease free riding. Yet, even in mandatory schemes, information campaigns should not be entirely neglected as they potentially increase acceptance of sanctions.

Future research should look at the ways in which non-compliant households can be motivated to sort their organic waste properly. Possible ways for that are different forms of incentives, fees and other sanctions, more intensive information provision or different measures combined. Questions to answer are which of these ways (or combinations) work best in which scenarios. Furthermore, future research could look at whether miss sorting is a problem that occurs at the household or individual level, similar to, for example, research on intra-household free riding in the context of water consumption as discussed by Jack et al. (2018).

Author contributions

All authors contributed to the research. The manuscript was written by the corresponding author. All authors have given approval to the final version of the manuscript.

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CRediT authorship contribution statement

Stefan Campos Mühlhoff: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Christian Herzig:** Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing. **Nikolas Zöller:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology. **Christian Bruns:** Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.wasman.2024.04.019>.

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