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**DOI**
10.1007/s10668-023-03707-x

**Publication date**
2023

**Document Version**
Final published version

**Published in**
Environment, Development and Sustainability

**Citation (APA)**
Piltz, G., Annema, J. A., & Pesch, U. (2023). Experts’ perspectives on the sustainability and risks of freely applicable MSWI bottom ash: A Q-methodology study in the Netherlands. *Environment, Development and Sustainability*, *26 (2024)*(10), 25785-25809. https://doi.org/10.1007/s10668-023-03707-x

Environment, Development and Sustainability (2024) 26:25785–25809
https://doi.org/10.1007/s10668-023-03707-x

# Experts' perspectives on the sustainability and risks of freely applicable MSWI bottom ash: a Q-methodology study in the Netherlands

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Received: 31 January 2022 / Accepted: 21 July 2023 / Published online: 25 August 2023


**Abstract**
Experts in the Netherlands have lately debated the novel policy idea to freely apply municipal solid waste incineration bottom ash (MSWIBA). In this paper, we map this ambivalent and unforeseeable, subjective, expert debate. This will help policymaking because more knowledge on subjective expert viewpoints and perceptions allows for clustering conflict and consent as well as gaps in common understanding in this complex debate. We applied Q-methodology which resulted in four distinct perspectives in the expert debate that reveal insights into the social licence to operate and into the legitimacy of the novel bottom ash regime. The freely applicable quality of BA itself is accepted in all perspectives. Conflicting views were found about new risks, trust and socio-political acceptance of the novel BA applications. An important practical contribution of this study is that a higher acceptance of the freely applicable MSWI BA quality in the Netherlands within the expert community can be achieved if the new risks of the free application regime are tackled. We are the first to use Q-methodology in this field, and our academic contribution is that we show that this method can be a helpful tool to unravel complex expert debates also related to MSWI BA applications.

**Keywords** MSWIBA · Q-methodology · Circular economy · Climate resilience · Construction material · Governance

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## 1 Introduction

Residual mineral bottom ash (BA) from municipal solid waste incineration (MSWI) can be disposed of as landfill or utilised for construction purposes, depending on national regulation, which differs highly among European countries (Blasenbauer et al., 2019). The Dutch way of using BA as a roadbed filler was seen as costly, likely to fail and inaccurate in regard to risks of leakages. Therefore, the government and the Dutch Waste Management Association (in Dutch: *Vereniging Afvalbedrijven*) examined other appropriate options. They concluded the Dutch Green Deal on BA that pushed the idea that all bottom ash may be applied as unrestricted construction material. From 2020, BA may be applied as additives in products, immobilised, and as non-moulded products that meet the requirements as laid down in the 'Soil Quality Decree for Free Application'. Furthermore, unforeseen innovative ideas are pushed within this Green Deal (Green Deal, 2018). The freely applicable quality is seen as the bottom ash quality with the highest value. This option demands high-level treatment processing of the bottom ash using wet and dry technologies (Rijksoverheid, 2018). The high-level treatment processing makes the residual mineral ashes ready for use in new novel high-end applications, which is attractive for the industry (Steketee & Langevoort, 2020b). This paper studies the contents of the expert debate on the quality of freely applicable bottom ash in the Netherlands.

In the literature on the reuse of MSWI BA for building and construction in past decades, much attention was especially paid to potential risks. Non-treated bottom ash has mainly been examined regarding leaching (Dijstra et al., 2005; Dung et al., 2018; Liu et al., 2008; Loginova et al., 2018; Meima & Comans, 1998; Xu et al., 2019). Thereby, the health and environmental risks from the reuse of MSWI bottom ash as a construction material were examined in different scenarios (Bouvet et al., 2007; Chen & Lin, 2006; Klymko et al., 2017; Shih & Ma, 2010; Yin et al., 2020). Furthermore, an analysis of the existing risks from the value chains of bottom ash in the Netherlands has shown organisational risks of stockpiling and suction effects (Inspection of the Living Environment & Transport, 2019). Regarding the risks of freely applicable bottom ash, scientific attention was also drawn to the production method. In Steketee and Langevoort's (2020b) paper, for example, a production method is presented that stabilises the leaching of trace elements by washing, carbonisation and mineralisation.

In the literature, the altered status of MSWI BA to a new anthropogenic material has been studied (Dijkstra et al., 2019) and quantifications for recovery and application are emerging in literature related to sustainability (Allegrini et al., 2014; Dou et al., 2017). The transformation is studied from environmental and health perspectives (Blasenbauer et al., 2019; Fletcher et al., 2017). Poranek et al., (2022a, 2022b) studied the technologisation of bottom ash to meet the sustainable development goals.

So, the body of scientific literature contains much on risk analysis, sustainability and the legal situation of BA applications. Meanwhile, the wicked character of the MSWI BA debate has not yet been researched in the scientific literature. By wicked character, we mean that a sustainability issue such as this implies manifold (scientific) uncertainties as well as underlying values and judgements (Pesch & Vermaas, 2020). Also, experts in a wicked issue often have differing opinions about the problem analysis, what the goal of policymaking should be and how this could be achieved. Thus, it seems relevant, in our view, to determine and appraise the ambivalent and unforeseeable expert knowledge on MSWI BA. Accordingly, by mapping this expert knowledge debate, stakeholder dialogue might be supported (Cuppen, 2011). The contribution of this paper is twofold. First, more knowledge of subjective expert viewpoints and perceptions allows for clustering conflict and consent as well as gaps in common understanding in this complex debate. Consequently, such insights can be useful in practice to adapt the direction of managing MSWI bottom ash applications (Brown, 2004). Scientifically, we aim to contribute by briefly reflecting on the value and usefulness of the Q-method in BA application debates. As far we have found, the Q-methodology we apply in this research (see below) has never been used in this field. Scientifically, we aim to contribute to the literature in this field by briefly reflecting on the value and usefulness of this method in BA application.

The main objective of this study was to contribute to a foundation for informed decision-making on novel material solutions for MSWI BA. Considering the vast amounts of BA, which are produced and treated in the Netherlands to be processed into a construction material of a higher value than ever, a discussion regarding the ethical acceptability of the technology will become increasingly important. To this end, this study can help to outline the matter of consent to facilitate informed decision-making and better risk governance. For this reason, this study particularly addresses decision-makers and stakeholders within the Dutch MSWI BA regime. Though this study is confined to the Dutch context and debate, we think that some important lessons can be learned from this study in other contexts. We will address the generalisability of this study in the discussion part of this paper (Sect. 5).

Q-methodology is used in this paper to identify the subjective viewpoints. The method was initially established by William Stephenson in the 1930s and was later developed by psychologists. Different from other well-known quantitative techniques that try to measure the spread and values of different perspectives, Q-methodology means to point out which views are shared (Eden et al., 2005). Rather than balancing the views among the population, the focus is on sampling different viewpoints by finding small purposive sample sizes that are assumed to have different views on the topics. The first step of this methodology is the identification of the concourse (what people say or think about the freely applicable bottom ash).

We explain the Dutch concourse about freely applicable BA in Sect. 2, based on a brief document review and some informal interviews. After this, the utilisation of Q-methodology is explained in more detail (Sect. 3), followed by the results (Sect. 4) and a discussion section on the acceptance of the material and the usability of Q-methodology (Sect. 5). The conclusion and recommendations are given in Sect. 6.

## 2 The Dutch concourse about (freely applicable) BA

In the Dutch concourse, two main drivers for freely applicable MSWI BA building materials can be identified. First, the porous characteristics of BA make this material suitable for preventing water stress and it can be adapted for instances of heavy rainwater (VP Delta, 2020; OTAR, 2019). Thereby, most innovative BA application fields suggested by experts are embedded strategies for climate resilience, such as the Deltaplan 'Spatial Adaptation' (*in Dutch:* Deltaplan Ruimtelijke Adaptie, hereafter Deltaplan), which is a collective arrangement of Dutch municipalities, water boards, provinces and the national government. This plan was made due to the growing built-up environment and more extreme cases of rain, which indicates that climate change is faster than predicted and needs a deeper understanding of resilience potentials (Kennisportaal Ruimtelijke Adaptatie, 2020). A second driver of BA reuse is the Circular Economy (CE) as a concept that stands high on the

Dutch political agenda (Rijksoverheid, 2016). Freely applicable MSWI BA reuse does not only exemplify reuse of a waste product from thermal recycling (ISWA, 2015), but was even validated to replace sand and natural stone, which are construction materials that will become increasingly scarce in the Netherlands (Anonymous expert, personal communication, 12.11.2020). This supports the idea of tackling the value chain problem of bottom ash, which is that the mineral fraction of the bottom ash is left with a negative value after the recovery of ferrous and non-ferrous metals (Inspection of the Living Environment & Transport, 2019).

A wide variety of perceptions regarding BA reuse are found in the discourse which seem to be widely related to the question of how incineration products should be seen in a Circular Economy and in sustainable societies. One of the main reasons for debate is the waste hierarchy, which was introduced by the EU waste directive of 2008 (EC, 2008), and by which waste incineration is seen as better than landfill but worse than all waste prevention approaches. From this perspective, some perceive the utilisation of MSWI BA as not being able to accommodate resource efficiency but stipulating the dependence on municipal solid waste as a non-renewable resource (Tsui & Wong, 2019). It is put forward by people in the debate that MSWI BA use can be considered as a waste supply-driven approach, while more demand-driven and waste-preventing approaches should be supported (Wilts & von Gries, 2015). From a different perspective, MSWI is seen by some as being essentially needed for the Circular Economy. Consequently, a new mindset and higher acceptance as a building or construction material is desired by some people in the debate (Wiel, 2016). A so-called End-of-Waste (EoW) status to make BA an even more desirable construction material has been discussed for quite some time but was, until now, amended due to environmental and health risks. The EoW status could reduce the administrative burdens and, if applied to construction products where bottom ash is used as an aggregate, could also provide extra certainty regarding quality and safety (Blasenbauer et al., 2019). In the Netherlands, a recycling label was given to freely applicable BA by which municipalities can include the reused bottom ash in their recycling inventories, which means that chances of reaching recycling targets are increased (Wiel, 2016).

Concerns about risks also play an important role in the current debate. Due to the early established, so-called ‘Soil Quality Decree’ a high level of environmental protection is granted in the Netherlands (Blasenbauer et al., 2019). This Decree (Bodem+, 2008) is also being used to establish the requirements for national guidelines for building materials (BRL-guidelines) connected to some other restrictions like mixing, which are specified in the sector plan for MSWI BA. Notwithstanding the many conditions that must be met for licensing the waste materials as building materials, the presence of Substances of Very High Concern (SHVC) inside the bottom ash minerals is still uncertain (Rijkswaterstaat, 2019). This uncertainty gives much debate on risks. Since washing is the dominant treatment method to produce a freely applicable BA quality, the sludge that leaches out by washing and that then leaves the washing installation is an important cause of environmental emissions from the freely applicable BA quality (Steketee & Langevoort, 2020b), which gives rise to concerns. Another important concern is the long-term effects of leaching of BA (Steketee & Langevoort, 2020a). Further chain-related risks are also part of the debate. These risks exist due to the negative incentives emanating from the current system of waste incineration. The Inspection of the Living Environment and Transport (Inspectie Leefomgeving en Transport) reports the profitability of waste imports for waste incineration, stockpiled BA, and environmental damage from storing BA, as well as suction effects from large infrastructure projects as the main problematic issues. While waste should be reduced in principle in practice, unintended effects occur due to landfill prohibition and application restrictions (Inspection of the Living Environment & Transport, 2019). Even though large-scale infrastructure applications have been advised by some industrial actors (ISWA, 2006), it has already been documented that these large-scale applications do not provide enough capacity for the total amount of reusable BA (Inspection of the Living Environment & Transport, 2019). Overall, it can be seen in the current discourse that BA projects are complex with an increasing number of stakeholders, which impacts planning and control, putting barriers to identifying shared goals and objectives and selecting a shared BA management approach (Burcar Dunovic et al., 2014).

## 3 Methodology

The Q-method is used to find the subjective viewpoints in the concourse. We follow a standard -5-steps as described in the standard approaches (e.g. Molenveld, 2020) (see Fig. 1). For the Q-sample, interesting statements from each part of the definition of the presented concourse on the sustainability and risk of freely applicable bottom ash were collected from articles and secondary literature, such as publications produced by waste management associations, oppositions and consultancies. Aspects such as global sustainability, the Circular Economy, climate resilience, 'waste-to-energy' and certification were important issues that the Q-sample should include, in connection with sustainability. Leaching, precaution, chain risks, the application for the Circular Economy and project complexity were the main aspects of risk that were identified. Two semi-structured interviews with two experts on freely applicable BA ($n=2$) were also carried out to identify powerful

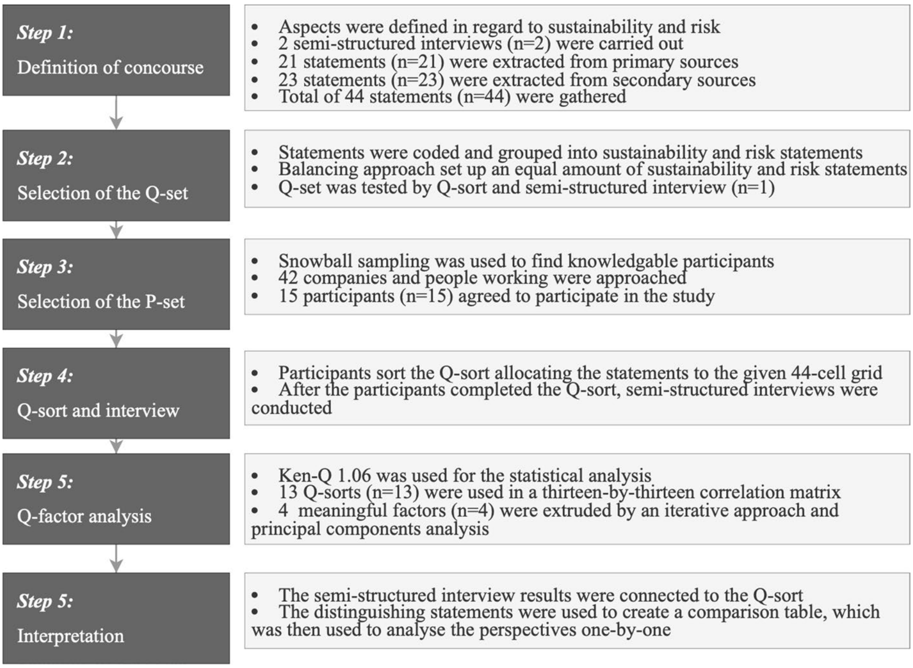


**Fig. 1** Research diagram

statements. This resulted in a list of 44 statements that were derived from primary ($n=21$) and secondary ($n=23$) sources. The statements from the primary sources were retrieved from the interviews ($n=11$), legislative and government documents ($n=3$), a journal article issued by the government ($n=3$) and journalistic opinion pieces ($n=4$). The statements from secondary sources were retrieved from journal articles commenting on or analysing research ($n=12$) and other newspaper or opinion pieces ($n=11$).

The statements collected were coded and grouped into sustainability and risk statements (in Table 2 next section the statements can be found). To attain a balanced Q-sample, the first balancing approach set up an equal number of sustainability and risk statements, while the second balancing approach facilitated an equal distribution of positive, negative and neutral statements. A semi-structured interview with a former researcher of a freely applicable bottom ash solution ($n=1$) was conducted. During this interview, the Q-sample was tested on the content of the statements and the underlying structure of the framework. In order to generate the P-sample, companies such as bottom ash processors and environmental consultancies were approached to select participants. Additionally, snowball sampling was used. Generally, this method is helpful to find participants that are part of a hidden population. It was used with the first Q-sample respondents, as well as the respondents to the first sub-question interview, as a starting point. In total, 42 companies and people were contacted, of which five ($n=5$) work in engineering and recycling, fifteen ($n=15$) are involved in the construction and building sector, nine ($n=9$) are from waste management, seven ($n=7$) are technical experts from consultancies, and six ($n=6$) are other foundations or companies working on environmental issues. In Table 1, the 15 ($n=15$) respondents that agreed to participate in the study and their field of work can be seen. The participants (P-sample) can be grouped into construction and built environment, waste management and consultancy (Table 1). As unbound freely applicable bottom ash is to be applied as construction material for new kinds of applications, experts from the construction and built environment are important stakeholders when it comes to the technical applicability and characteristics that it must fulfil. All participants of this group work as project managers or innovation managers. The group of participants working in waste management is important due to the know-how of the developments of the value chain of applicable bottom ash, but also regarding ideas about the future of the industry. Most participants work as project managers and business developers for bottom ash in different qualities. The consultant group is mainly distinguished by their advanced knowledge of sustainability and risk concepts, certification and legislation. The pilot interviewee was involved in the research for the leaching limits, in line with the Soil Quality Decree, and is thereby often consulted for bottom ash-related issues.

The interview sessions with the 15 respondents took place during October, November and December 2020 and lasted between 60 and 90 min. Due to the Corona pandemic in the year 2020, the interviews had to be conducted online, which did not change the procedural steps, but the way of execution. About half were conducted in English and the other half in

**Table 1** Respondents and their field of work

| | Number of respondents | Respondent # |
|---|---|---|
| Construction and built environment | 4 | 1, 2, 4, 14 |
| Waste management | 6 | 3, 6, 9, 11, 12, 15 |
| Consultancy | 5 | 5, 7, 8, 10, 13 |

Dutch. As part of a structured interview, the respondents were first asked to describe their work and their general ideas on freely applicable bottom ash. Then, the Q-sorting started by reading through all statements together and rough sorting the issue (agree, disagree, doubtful, etc.) marking the pre-sorts in colour, instead of putting them in piles. Next, these statements were sorted into the framework (Fig. 2), beginning with the negative rated ones, then moving on to the positive rated ones and ending with filling in what they rated neutral.

The Q-sorting was complemented by questions like 'Why are these statements extreme?', 'Do you miss specific aspects?' and 'Would you like to go back to add something to your answer on my earlier question about your ideas on sustainability and the risks of novel (freely applicable) MSWI bottom ash solutions?'. A pilot Q-sort interview with a technical expert ($n=1$) was organised to find out any missing angles and thereby any applicable statements, and about the validity of the balancing approaches. Before the actual Q-sorts were conducted, the framework could then be adapted, incorporating the outcomes of the pilot Q-sort. It was adapted that earlier IBC-quality materials used in construction also had advantages, as their implementation was well-registered and protected from water, which prevented risks of leaching. Further precaution was acknowledged regarding aspects such as bioavailability impacting the uptake of contaminants along the food chain, and that freely applicable bottom ash can be used anywhere, which were the main aspects that were added to the Q-sample.

After the interviews were conducted, the statistical analysis took place, helped by the web application of Ken-Q analysis 1.06 (Banasick, 2019). Thirteen Q-sort distributions could be used to create a thirteen-by-thirteen correlation matrix, presenting the level of similarity or dissimilarity between all Q-sorts. Taking an advised cut-off rule into account correlation scores greater than 0.8 (Samuels, 2016), none of the respondent's Q-sort had to be ruled out due to too high similarity. In the following step, a factor analysis was conducted by showing how many respondents share the same factor. The factor loading shows the extent to which Q-sorts are associated with the pre-established factors (Brown, 1993). With the assistance of the Ken-Q analysis tool, meaningful factors were extruded with an iterative approach going back and forth from different types of factor extraction and rotation. To make sense of the extruded factors, the data needed to be reviewed qualitatively. It was decided to use the approach of principal components analysis, as this analysis is more exploratory than the centroid factor approach, which has a more confirmatory character. Eight initial factors were extruded using this method. From the unrotated factor matrix, the Eigenvalues of the factors 6 and upwards fell under 1, meaning that these cannot explain

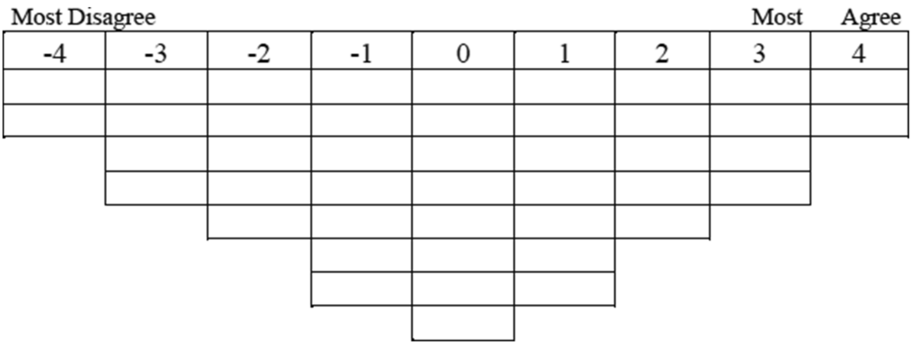


**Fig. 2** Q-sort distribution

one other item. Choosing five factors resulted in unbalanced results with only two distinguishing statements for two factors. Therefore, four factors were selected for varimax rotation, which determines a richer picture of the extruded factors.

For the interpretation, the structured interview results were connected to the statistical analysis. The distinguishing statements that were positively or negatively rated were used to create a comparison table. This table was then used as a tool for describing the perspectives one-by-one. For this description, the qualitative interview results were used to give further insight into their mind-sets. The links between social, psychological and normative results were made by presenting theoretical and practical implications for the degree of acceptance of (freely applicable) MSWI BA solutions and the plurality of perspectives.

## 4 Results

Table 2 shows the statements used and the resulting factor arrays.

The respondents' general idea about the freely applicable quality of bottom ash was neutral or rather positive. The reuse of materials, as well as the technical feasibility, of climate adaptive solutions was endorsed. Furthermore, the implications of the Green Deal, such as the ban on the IBC-quality and other BA solutions within concrete, for example, were discussed. Two respondents could not force their ideas into the Q-sorting frame; one of which argued that a classification system would be better to guarantee freedom of choice. These flaws within the method that were identified became apparent in another case of the Q-sorting sessions when a respondent pre-sorted almost all the statements to the positively agreed pile. In this case, the differentiation seemed hardly possible, and it became clear just how subjective the method can also be, in practice. Even though this respondent could not complement the Q-sort, this respondent's argumentation about the statements was still helpful for interpretative purposes.

Table 3 shows the factor loadings and the marked, auto-flagged, relevant factor loadings, and it shows that factor 1 is most represented by four flagged Q-sorts, while all the other factors are loaded with two sorts.

Generally, 7–13 statements distinguish the four factors (perspectives) from each other at a significance level of 5 or 10%. Furthermore, a list of five consensus statements could be generated, which do not distinguish between any pair of factors.

The four calibrated factors result in four main perspectives. In the following paragraphs, these perspectives will be described one-by-one, followed by a description of the consent areas. Table 4 gives an overview of the main distinguishing values of each perspective.

### 4.1 The precaution perspective

From this perspective, freely applicable bottom ash is seen as an advancement regarding the leachability, but its non-natural composition and the potential of SVHCs should not be neglected. It is notably highlighted that generally IBC-regulations ('isolate, maintain and control') for BA is a good solution. An example of this viewpoint could be found with respondent 4, who confirmed that the IBC-regulation from the Soil Quality Decree was very clear about what can be done and how it must be applied. From the precaution perspective it is emphasised that freely applicable bottom ash should not spread everywhere. For this reason, former IBC-application fields, such as road fillers or high-way noise barriers, are still considered to be appropriate, as they allow certain amounts to be used at once.

**Table 2** Statements and factor arrays

| Numbered statement | Source | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|---|
| 1. It is a problem that large infrastructure projects might lead to a suction effect by which more bottom ash gets imported and stock-piled in NL | Inspection of the Living Environment and Transport (2019) | – 3 | – 3 | 3 (D*) | – 3 |
| 2. As the freely applicable quality is only produced by a few of the 16 WtE plants, the implementation in general is more complicated | Inspection of the Living Environment and Transport (2019) | – 3 | – 1 | – 3 | – 1 |
| 3. Clean raw materials from bottom ash belong in the same category as compost from, kitchen and garden waste, glass, plastic and waste paper | Wiel (2016) | – 2 | – 1 | 1 | 1 |
| 4. Energetic recycling by waste-to-energy must actually be restricted as it causes collective health risks and puts barriers on material recycling | Circular Futures (2020) | – 1 | – 1 | 1 (D) | – 3 (D) |
| 5. The drivers can also cause drawbacks in the appropriate use of waste-derived-aggregates for example building high-way noise barriers from treated aggregates should be considered as dumping to avoid high waste tax costs for landfilling | Sormunen (2017) | – 4 (D*) | 1 | 0 | – 1 |
| 6. It is good that municipalities can add reused freely applicable bottom ash to their recycling inventories because chances to reach recycling targets are increased | Wiel (2016) | 1 | 1 | 1 | 2 (C) |
| 7. You can call the implementation of freely applicable bottom ash in construction reuse but it's not the best option in terms of sustainability. High national waste-to-energy capacities are still inconsistent with recycling targets and circular economy impacts in terms of decarbonisation and meeting the Paris Agreement target | Anonymous expert (personal communication, 01.10.2020), European Commission (2017) | 0 | 1 | 4 (D*) | – 2 (D*) |
| 8. A main advantage is that time and cost reductions can be achieved by using bottom ash in construction | de Broer (2019) | – 2 (C) | 0 (C) | 0 (C) | – 2 (C) |
| 9. Research on the desirability of an EoW status based on construction products of freely applicable bottom ash must be extended, especially in the light of growing incinerator capacities and changing market conditions in the construction sector | Fletcher et al. (2017) | 0 | 3 (D*) | – 4 (D) | – 1 |

**Table 2** (continued)

| Numbered statement | Source | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|---|
| 10. Due to the Green Deal, sustainability objectives and goals in terms of circular use of bottom ash can be well aligned | Green Deal (2018) | − 1 | 0 | − 2 | 2 (D) |
| 11. Transparency in regard to the freely applicable quality itself and supervision will improve trust in that the material has higher value that IBC-quality | Partij voor de dieren Friesland (2019), SIKB (2018) | 1 | 4 | − 1 | 3 |
| 12. Freely applicable bottom ash production complements a recovery system that is real urban mining | Blommaert (2018) | 3 (D) | 0 (C) | 0 | 1 |
| 13. Double counting for recycling targets and other targets must be prevented | Anonymous expert (personal communication, 01.10.2020) | 1 | − 2 (D*) | 2 | 2 |
| 14. An End-of-Waste status for freely applicable bottom ash (as produced in the NL) should be amended due to environmental and health risks | Blasenbauer et al. (2019) | 2 (D*) | − 2 | − 1 | − 3 |
| 15. Circular economy may actually give the WtE system the opportunity to strengthen and expand its role towards new or little developed value chains such as secondary raw materials production and valorisation of new waste streams occurring in material recycling | Lausselet et al. (2017) | 2 (D*) | 0 | − 4 (D*) | 0 |
| 16. It is a barrier that Dutch waterboards are important stakeholders that always for the safe | Anonymous expert (personal communication, 12.11.2020) | − 1 | − 2 | − 2 | − 4 |
| 17. The Netherlands are very much forward thinking when it comes to handling municipal solid waste and treating bottom ash. This gives a sense of legitimacy but it also makes criticism more difficult because there might be no better options to this moment | Anonymous expert (personal communication, 01.10.2020) | 0 | − 2 | − 3 (D) | 0 |
| 18. Environmental damage from stockpiling is a tax payer's issue and will it should be invested into carbonisation and washing where there is space of bottom ash stockpiling | Inspection of the Living Environment and Transport (2019) | − 1 | − 1 | 2 | 1 |
| 19. The government can also make mistakes because bottom ash is a stream that you don't want to bring in from another country | BNNVARA (2018) | 0 | 1 | 2 | − 2 (D*) |

**Table 2** (continued)

| Numbered statement | Source | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|---|
| 20. Since IBC-materials were used (dumped) in a lot of places without appropriate documentation and monitoring the public has many questions regarding leaching of freely applicable bottom ash | BNNVARA (2018), Partij voor de dieren Friesland (2019) | − 1 | 3 (D*) | − 1 | 0 |
| 21. It is good that freely applicable quality got validated by Rijkswaterstaat as alternative for sand and gravel | Anonymous expert (personal communication, 12.11.2020) | 2 | 2 | 0 (D) | 3 |
| 22. There is a variety of stakeholder perspectives about freely applicable bottom ash. Maybe it's one of the products with most diverse opinions on it | Anonymous expert (personal communication, 01.10.2020) | 1 (C) | 0 | 0 (C) | 1 (C) |
| 23. Immobilisation by for example putting the material into concrete is not the future of bottom ash because then it degrades the quality. When the concrete is broken it can leach again | Steketee and Langevoort (2020a) | 3 | − 4 (D*) | 3 | 0 |
| 24. I trust in the strict quality requirements due to the Soil Quality Decree and also other upstream organisations that registering chemicals and REEs in products that can be incinerated | Rijkswaterstaat (2019a) | 0 | − 2 (C*) | − 1 | 2 (D*) |
| 25. Flows of rare earth elements have to be controlled by improving the waste treatment and regulations of Rare Earth containing Products | Allegrini et al. (2014) | 1 | 4 | 2 | 1 |
| 26. Waste management and WtE capacities are managed with a supply side approach while actually demand-driven and waste-preventing approaches must be supported | Wilts and von Gries (2015) | 1 | 3 | 3 | − 1 (D) |
| 27. Transparent decision-making procedures of freely applicable bottom ash use for water stress preventing construction projects will support its legitimacy in regard to climate resilience | Keessen et al. (2013) | − 2 (D*) | 1 | 1 | 3 |
| 28. Goals and objectives concerning the circular economy can clash when considering MSWI bottom ash for reuse | Anonymous expert (personal communication, 01.10.2020) | − 2 | 2 | 1 | − 4 (D) |
| 29. The biggest sustainability driver for freely applicable bottom ash is that it has better characteristics than sand, even though it is not natural and requires norms | Anonymous expert (personal communication, 12.11.2020) | − 2 | − 3 | 1 | 0 |

**Table 2** (continued)

| Numbered statement | Source | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|---|
| 30. There are many uncertainties in the innovation system. An End-of-Waste status for processed construction products from freely applicable bottom ash would provide extra certainty (quality and safety) | Fletcher et al. (2017) | − 1 | 1 | − 2 | − 1 |
| 31. Freely applicable bottom ash contributes to a wide number of goals in regard to circular economy, climate resilience, the local use of resources as well as the replacement of sand and gravel | OTAR (2019), VP Delta (2020), Wiel (2016) | 1 | 0 | − 3 (D*) | 4 (D*) |
| 32. Some risks of free application of specifically MSWI bottom ash are not taken into account in the current legislation, like that organisms can get in direct contact with the material, dust particles that could spread by the wind, or new applications such as spreading out in public spaces like parks and gardens | Steketee and Langevoort (2020a) Anonymous expert (personal communication, 19.11.2020) | 2 (D*) | − 1 | − 2 | − 2 |
| 33. Building with freely applicable bottom ash will support municipalities with their water stress problems | Granova (2021) and Duurzam Actueel (2018) | − 3 | − 3 | 0 | 4 |
| 34. Former IBC-applications were generally considered safe as they left no water in and were well controlled and registered | Anonymous expert (personal communication, 19.11.2020) | 4 (D*) | − 4 (D*) | 1 | 1 (D*) |
| 35. We need a new mindset as the WtE plants should not only be judged on their energy performance, but also on the materials that are recovered and reused as building materials or for other purposes. These are clean products that can be used as direct replacements for primary raw materials | Wiel (2016) | 2 | 0 | 0 | 1 |
| 36. All freely applicable qualities should approach high-end markets | Anonymous expert (personal communication, 12.11.2020) | − 3 | 1 (D*) | − 2 | − 1 |
| 37. Risks can be reduced by longer use durations of bottom ash aggregates | Shih and Ma (2011) | 0 (C*) | − 1 | − 1 (C*) | − 1 (C*) |
| 38. Municipal Solid Waste Incineration does not provide any resource efficiency which helps to prevent material shortages. It rather stipulates the dependence on municipal solid waste as a new anthropogenic non-renewable resource and also encourages wastefulness, which is unethical and unsustainable | Tsui and Wong (2019) and Böhm and Valenzuela (2017) | − 4 | − 3 | 4 (D*) | − 2 |

**Table 2** (continued)

| Numbered statement | Source | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|---|
| 39. Waste-to-energy by waste incineration is essentially needed for the circular economy since it serves to keep material cycles clean from hazardous substances and advances the circular economy by recovery of energy from non-recyclables, which would else be landfilled | Van Caneghem et al. (2019) | 3 | 2 | − 3 (D*) | 0 |
| 40. Acceptability of freely applicable bottom ash is also dependent if the production method includes accelerated ageing by carbonation or just washing | Steketee and Langevoort (2020b) | − 1 (C*) | − 1 (C*) | − 1 (C*) | 0 (C*) |
| 41. The sustainable application of processed MSWI bottom ash is an essential part of the intended transition to the desired circular economy, in which all solutions for bottom ash that are included in the Green Deal are needed | Steketee and Langevoort (2020a) | 0 | 0 | 2 | 3 |
| 42. To become a real circular system, freely applicable bottom ash must also be reused | Rijkswaterstaat (2015) | 3 | 3 | 0 (D*) | 2 |
| 43. I think it is a problem that waste is imported due to profitability of WtE | Inspection of the Living Environment and Transport (2019) | 0 | 2 | 3 | − 3 (D*) |
| 44. Direct risks of leaching are reduced with the freely applicable quality but uncertainties of its non-natural composition should not be underassessed | Anonymous expert (personal communication, 19.11.2020) | 4 (D) | 2 | − 1 | 0 |

*C* consent, *D* distinguishing

**Table 3** Factor loadings of the respondents

| Q-sort | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Field of work |
|---|---|---|---|---|---|
| Respondent 1 | − 0.0358 | 0.2357 | − 0.1771 | 0.6606* | Building and construction |
| Respondent 2 | 0.0764 | − 0.1246 | 0.3023 | 0.7244* | Building and construction |
| Respondent 3 | 0.0669 | − 0.234 | 0.8253* | − 0.067 | Waste management |
| Respondent 4 | 0.6384* | 0.0125 | 0.0579 | 0.2408 | Building and construction |
| Respondent 5 | 0.3679 | 0.07 | − 0.4204 | 0.6992* | Consultancy |
| Respondent 6 | 0.3922 | 0.2505 | − 0.4352 | 0.396 | Waste management |
| Respondent 7 | 0.2115 | 0.8293* | 0.0354 | − 0.1438 | Consultancy |
| Respondent 8 | 0.7933* | 0.1019 | − 0.1609 | − 0.2172 | Consultancy |
| Respondent 9 | 0.6821* | 0.0261 | 0.1268 | 0.2192 | Waste management |
| Respondent 10 | − 0.1567 | 0.824* | − 0.0064 | 0.2602 | Consultancy |
| Respondent 11 | 0.4537 | 0.516 | − 0.3042 | 0.2313 | Waste management |
| Respondent 12 | − 0.0661 | 0.3317 | 0.6544* | 0.0364 | Waste management |
| Respondent 13 | 0.4957* | 0.0011 | − 0.0712 | − 0.0098 | Consultancy |
| % Explained variance | 18 | 15 | 13 | 15 | |

While the Circular Economy is still seen as an important driver for the reuse of bottom ash in this perspective, the application for climate resilience and utilisation against waterlogging are questioned. This rather conservative perspective also relates to amendments of the End-of-Waste status and calls for IBC-based regulation and risk management.

## 4.2 The quality perspective

In contrast to the first perspective, the quality perspective questions the safety of the former IBC-application. There are different reasons given in this perspective as to why this quality is error prone. One reason is that a lot of the monitoring and documentation went wrong in the past, so it is no longer understood where much of the bottom ash lies. This was related to a bottleneck of manpower, meaning the lack of skilled public authorities, who should have taken care of the documentation. Additionally, in this perspective, technical mistakes have led to the situation that practice did not turn out to be as good as the theory. Issues like certain coverage layers needed, soil structures and ground water levels, especially in the western part of the Netherlands, complicated the issue of correct implementation. From these lines of reasoning, the achievements of the Green Deal are highly desirable in this perspective, as the former quality is banned and other bottom ash solutions are made possible. It is seen that the Dutch developments regarding bottom ash are consistent in improving the quality, which provides legitimacy of actions. Mainly, the general reuse of BA is stipulated, whether applied as freely applicable material or in an immobilised way, which is criticised due to life cycle issues. It is seen that an End-of-Waste status for freely applicable bottom ash could provide many benefits and needs to be explored.

## 4.3 The circular economy-concerned perspective

The central idea of the Circular Economy-concerned perspective goes back to the role of the waste-to-energy system as a part of the Circular Economy. The main problem seen in

**Table 4** Perspectives of freely applicable bottom ash (grey = from risk statement, white = from sustainability statement)

| The precaution perspective (factor 1)<br>Precaution and the application for a circular economy | The quality perspective(factor 2)<br>Leaching, certification and application | The CE-concerned perspective (factor 3)<br>Waste-to-energy and the circular economy | The Green Deal perspective (factor 4)<br>Trust in the sustainable solution and new application fields |
|---|---|---|---|
| Former IBC-applications are safe | Former IBC-applications are not safe | WtE should be restricted | WtE should not be restricted |
| IBC-application possibilities are good | Immobilisation is a good alternative | WtE is not resource efficient | Water stress application is important |
| EoW needs amendment | Research on an EoW needed | Less WtE must be achieved | BA reuse is fully circular |
| Precaution concerning non-natural composition of freely applicable BA | IBC caused mistrust | CE does not give WtE a new role | Waste imports for WtE are approved |
| Legislation needs to cover risks | Dutch BA developments are consistent | Suction effect is problematic | Bottom ash import is accepted |
| CE gives WtE a new role | Double counting is not problematic | WtE needed CE | Quality requirements are trusted |
| Freely applicable BA is climate resilient | Value applications are good | Dutch BA developments are consistent | Green Deal on BA supports CE |
| BA reuse is fully circular | | Freely applicable BA is not fully sustainable | Freely applicable BA is sustainable |
| BA recovery is urban mining | | EoW needs no amendment | No waste-preventing approaches |
| | | Research on EoW not needed | Research on EoW is not needed |

this perspective is that supply-based approaches do not promote material recycling and do not promote resource efficiency. Achievements regarding global sustainability targets could be hampered if today's waste-to-energy capacities are retained. With this perspective, it is stipulated that high WtE capacities are not in line with the global sustainability targets, such as the Paris Climate Agreement or the SDGs. It is feared that more BA could be stockpiled in the Netherlands due to so-called suction effects, meaning bottom ash imports that derive from large demands for bottom ash. Regarding freely applicable bottom ash, an End-of-Waste status does not seem particularly necessary. On the one hand, respondent 12 said that it should be used for scrap metal or plastics, but not bottom ash, and on the other hand, respondent 3 explained that the status is not really necessary in the Netherlands, but it is for other countries where regulation has not yet achieved better quality and certainty for the material. Generally, this perspective is very much focused on sustainability and sees the developments of bottom ash as sustainable. However, freely applicable bottom ash can only be seen as a solution if the capacities are managed well and do not create any waste or bottom ash dependency.

### 4.4 The Green Deal perspective

This perspective is highly optimistic about the sustainability of the material, and it shows pure trust in the circularity of the material, as well as the potential to solve issues of water logging. The value that BA achieves through these new fields of application is pointed out in this viewpoint. Overall, it has full trust in the quality requirements along the value chain and the market. The advocacy of BA imports, as well as the viability of waste-to-energy leading to waste imports, demonstrates a liberal nature to this perspective. A rather adverse attitude towards risk and a defensive stance about the Green Deal and bans of the IBC-material. To illustrate, as one respondent claims, the Green Deal has been the leverage that started the WtE plants improving bottom ash and improved circularity. Also, it was said that reuse of bottom ash for construction can be seen as upcycling since it transfers waste into a building material. Thereby, freely applicable bottom ash is accepted as a wholly sustainable quality.

## 5 Discussion

The first part of the discussion deals with the experts' viewpoints on the sustainability and risk of freely applicable MSWI BA. It provides the public debate with information about the stage of acceptance of the quality of the new material, as well as about the Green Deal, through which this quality is politically driven, and it thereby provides a foundation for informed decision-making on novel solutions for freely applicable MSWI BA. Q-methodology itself is known to facilitate stakeholder dialogue and thereby learn about innovation processes and sustainability. The main stages of stakeholder dialogue are: (1) preparing a diverse stakeholder sample; (2) articulating the perspectives of the dialogue; (3) confronting the stakeholders with their judgements and values; and (4) synthesis (Cuppen, 2011). In this study, the first two phases of stakeholder dialogue were researched. For this reason, the use of Q-methodology for stakeholder identification and selection and the articulation of perspectives in the MSWI BA debate is discussed. Lastly, suggestions on how to deal with the plurality of viewpoints will be proposed.

### 5.1 Acceptance of freely applicable bottom ash

The views of the interviewees (project managers from building and construction, waste management and consultancy) on the freely applicable BA can be split into four distinctive perspectives (see Table 3 and below). In all four perspectives of freely applicable bottom ash as innovative technology, this technology is accepted. The Dutch BA Green Deal as a leading policy, which enacted the ban of the IBC-quality and fostered the implementation of freely applicable bottom ash, seems to be the pivotal point of the debate. The 'Quality perspective' agrees with the Green Deal: that the former IBC-quality should be banned. From this perspective, both the freely applicable and the immobilised qualities are approvable solutions and technological advancements, but trust in the regulatory regime of BA must be recovered for full acceptance. From the 'Precaution Perspective', the Green Deal insufficiently addresses new risks from the free application like bioavailability and spreading (of dust particles) that should be covered by regulation. Therefore, the advantages of IBC-regulation are put forward in this view. These advantages are the allowed use of specific amounts, the documentation on where the material is used and the protection from water and spreading of dust particles. In that sense, the 'Precaution perspective' as well as the 'Quality Perspective' diverge from the 'Green Deal perspective' regarding views of technological advancement because they do not approve of freely applicable bottom ash as a solution for water stress. One of the main reasons seems to be the agreement with former IBC-quality standards, which suggest that BA has to be shielded from water so that water contact applications are not seen as appropriate. In this sense, also experts of bottom ash waste management in the building industry derive that it is important where the technology is installed (Poranek et al., 2022a, 2022b).

Furthermore, it becomes clear that the socio-political acceptance of freely applicable bottom ash and the Green Deal are also largely connected to other policy goals, such as waste-to-energy within the Circular Economy. From the 'Circular Economy-concerned perspective', the way that waste-to-energy gets framed as sustainable within the Circular Economy is criticised because the role to valorise waste streams and keep material cycles clean should be seen as a general societal service and not necessarily a service for the Circular Economy. In line with the waste hierarchy, this perspective demands more measures of waste prevention and material recycling and consideration of the profitability of waste-to-energy as a driver of chain risks in the system of bottom ash. The dynamics due to the sustainable procurement of new waste prevention or upstream control of SVHC in products, as well as new policies that lead to carbon efficiency of the incineration plants like $CO_2$ taxing of WtE producers or technology, such as $CO_2$ capture and carbon capture utilisation (CCU) from MSWI plants (the capture of $CO_2$ for use as a chemical building block) may have a significant effect on the socio-political acceptance of freely applicable bottom ash. Above all, policy can achieve such impacts by improvements of resource appropriation, control and maintenance of energy as well as sustainable technology development (Du et al., 2022). This is why further research of acceptance could take these three factors into account.

### 5.2 Q-methodology for stakeholder identification and selection, and the articulation of perspectives in the MSWI BA debate

Did we find all perspectives in this policy domain? Knowing the full diversity is key to enhancing the quality of knowledge needed for policymaking on issues such as MSWI BA. To achieve diversity for proper stakeholder dialogue, the identification must go further than the lay-expert distinction. It is argued that the lay participants should have the 'optimal cognitive distance', meaning that the information they are confronted with is not entirely new, but sufficiently new, so that a learning effect can be achieved (Cuppen, 2011). In this research, we made use of innovative niche stakeholders that make use of freely applicable MSWI BA for circularity or climate resilience reasons, consultants working from private and independent consultancies and research institutions, SMEs and bottom ash producers and processors. The NGOs and interest groups contacted handed over the interview request to their consulting partners because they had too little knowledge themselves. Thereby, governmental institutions, municipalities, water boards, consumers, distribution and storage centres, as well as upstream exploration companies, were not considered. Overall, the experts who were interviewed by us held very different kinds of knowledge, experience and interests that are relevant to define a broad sample. However, it must be said that no waste-to-energy or production plant of freely applicable bottom ash is represented in the final sample because the representative actor in the sample stepped out due to subjective problems with the statements. Overall, the topic seemed quite sensitive to the interviewees. In order to make the study on perspectives on freely applicable MSWI BA complete and more transferable, more decision-making parties, such as municipalities and water boards, could be included in the P-sample.

The articulation of perspectives was made possible by Q-sorting the list of 44 statements. The pilot interview opened a completely different perspective and led to the integration of the aspect of precaution in the framework. As the results from the statistical analysis show, this perspective was represented by the most participants. For this reason, more participants with broader knowledge on specific conditions or visions concerning the materials can lead to a more exploratory framework. Even more viewpoints could be possible, especially considering the regulatory changes, like carbon taxing of waste-to-energy plants from 2020, or from novel technologies like CCU. Apart from this, experts of comparable technologies claim these technologies cannot compete with standard linear production if not being subsidised so subsidisation and innovation could also derive further perspectives on the topic (Biakhmetov et al., 2022). The changes of subjective opinions might become increasingly detached from the role of the waste-to-energy system. As was indicated by one respondent, this framework mainly makes an issue of the organisational side of bottom ash, whereas there are also more environmental aspects that were touched on in the discussion and could enter the discourse. From a Life-Cycle-Analysis perspective, it would also be possible to investigate the bottom ash material from the point of production. In this case, the framework would exclude the aspect of waste-to-energy, which is dominant in the issue of acceptance. From another angle, the market effects of the prevention of waste, better pre-sorting, and more efficient incineration were suggested. Lastly, the Q-sample could be improved by a broader look at the image resulting from problems with the IBC-quality, reliability of bottom ash materials and communication in terms of Greenwashing.

### 5.3 Plurality of perspectives

Looking at sociotechnical progress, often the presence of different feasible perspectives on pathways of governance are overlooked. These perspectives can present conflicts of ambiguous socioeconomic and environmental interests and values. As Savaget and Acero write: 'Demystifying techno-determinism, by incorporating a plurality of understandings to policy appraisal, becomes a matter of not only democratic accountability but also of analytical rigour' (Savaget & Acero, 2017). Consequently, the plurality of perspectives in the discourse on freely applicable MSWI BA reveals disagreement among the experts concerning the path that climate mitigation and adaptation will take, and this gives rise to inconsistencies in the discourse.

The interpretations of resource efficiency as a basic concept of the Circular Economy diverge. The third perspective particularly shows that material recycling needs to be fostered while the high waste incineration capacities in the Netherlands are not compatible with the Paris Climate Agreement. New carbon taxonomy on waste incineration plants that have just been enforced could change this perspective. Though it can be learned that this narrative emphasises that more action needs to be taken upstream in the value chain.

While the presence of SVHC in the waste material (in terms of higher concentrations) is uncertain to some degree, the upstream control of SVHC is especially important considering the Circular Economy and the application pathway of freely applicable MSWIBA. However, this aspect poses rather high uncertainties. For this reason, perspectives with higher trust in policymaking deviate from the rest. Similarly, the confidence in applicability for drainage purposes and climate resilience also varies. While some actors fully acknowledge the new perspective that climate resilience strategies give to niche application fields for MSWI BA, other narratives do not trust the developments due to former restrictions on MSWI BA whereby it should not get in contact with water to avoid leakages. Consequently, making the quality material a substitute for sand presents high inconsistencies for some narratives. The plurality of perspectives ranges from a highly precautious perspective that puts forward the risks of the free application regime and the non-natural composition that have not yet been properly assessed under current legislation, to one that fully trusts the sustainability potential of the material.

In order to gain trust for the development of MSWI BA for different applications as a foundation and aggregate material, the plurality of the perspectives, especially in view of their risks, should be made explicit, negotiated and integrated into policymaking. Inclusive risk governance is expected to integrate knowledge and values in the decision-making process in a way that is effective and fair. To make acceptable decisions on risk, the more diverse actors in the risk arena should be approached. According to the findings of this study, it is questionable whether environmental research has addressed the research needs and objectives of an appropriately diverse group of stakeholders and thus limited this kind of institutional bias. In particular, the validation as an alternative for sand, in combination with the free application regime, provokes the fact that bottom ash, which is still considered to be a contaminated material by experts, can be treated like soil or assessed like soil. This also induces a socio-cultural bias as described by Huesemann (2002). Decision-making on the sensible applications and their appropriate communication for a Circular Economy needs to become more transparent and could be fostered by a stakeholder dialogue.

# 6 Conclusion and recommendations

In the Netherlands, plenty of bottom ash will be generated in the upcoming years to allow for significant growth, safeguarding the production potential of freely applicable materials. The development of this application quality of BA is particularly driven by the government through research and innovation projects, because the Netherlands has relatively few primary raw materials, such as natural stone, sand or gravel. Furthermore, freely applicable materials are thought to unlock opportunities for minimising waterlogging in the public area—for example, as a foundation layer underneath pavement.

In this study, Q-methodology was used to analyse the subjective viewpoints of 15 experts from the fields of building and construction, waste management and consultancy on freely applicable MSWIBA. Our motivation to use Q-methodology to map the complex debate has been based on the assumption that more knowledge on subjective expert viewpoints and perceptions allows for clustering conflict and consent as well as gaps in common understanding in this complex debate. The analysis resulted indeed in four distinctive and well-explainable perspectives: (1) the Precaution perspective with a relatively high focus on the application risks of freely applicable bottom ash; (2) the Quality perspective with a focus on the risks of the former IBC-quality; (3) the Circular Economy-concerned perspective that emphasises the values of the role of waste-to-energy in the Circular Economy concept and (4) the Green Deal perspective that appreciates freely applicable MSWI BA as sustainable construction material for climate mitigation and adaptation strategies.

In all perspectives, there is a wide consensus that freely applicable MSWI BA itself can be seen as acceptable, especially due to the reduction of leaching potentials. Also, it is widely supported that the reuse of the freely applicable MSWI BA should be taken up in municipal recycling inventories. However, the Dutch Green Deal on BA has led to conflicting views because precautious experts criticise that the regulation does not cover new risks arising from the 'free application' regime. Opening freely applicable bottom ash to more meaningful climate-resilient applications has raised fears that the non-natural composition and presence of SVHC could be ignored. These fears relate to the communication of freely applicable MSWI BA as a substitute for sand and testing it for water stress prevention and drainage systems. Apart from that, trust in the sustainability potentials of the technology is hampered by the manifold problematic issues with the former quality, which seem to have reduced the credibility of the Dutch BA system. Lastly, the acceptance of BA itself is dependent on the socio-political acceptance of WtE, which was presented by one perspective that sees MSWI as a societal service and calls for higher waste prevention and resource efficiency along the value chain.

## 6.1 Implications for practice and policymaking

Our results show practical implications for further consistency in BA developments. One implication is that a higher acceptance of the freely applicable MSWI BA quality in the Netherlands within the expert's community can be achieved if the risks of the free application regime are tackled. Risks related to the emissions of dust particles, exposure of organisms that can be in direct or indirect contact with the materials, as well as the long-term leaching potentials (especially of antimony and sulphate), were until now rejected, as the current assessment system only concerns the leaching of the building material at the point of application. It is recommended that the free application regime could take up certain restrictions of the former IBC-regime, such as a minimum size of the application and registration requirements for the type of application. Apart from that, mixing freely applicable BA with other non-shaped building materials, which could potentially lead to uncontrolled distributions into the environment, could also be examined. Additionally, further tests that demonstrate potential leaching during the usage phase are deemed imperative to provide insights into the long-term leaching behaviour.

Our Q-methodology study showed consensus but also diverging views. Facilitating better decision-making as well improved sustainability and risk communication about the freely applicable MSWI BA could therefore imply to have improved stakeholder involvement programmes with diverse groups of experts (e.g. waste management associations, municipalities, environmental organisations, researchers, citizens groups, etc.), who are in this way able to formulate their needs and objectives. Such programmes can be scientifically supported by a further study on the views of municipalities and water boards on freely applicable MSWI BA.

Finally, we propose not to lose track of waste prevention as the overall goal of a Circular Economy. Experts mentioned the fear of a possible lock-in effect by which high WtE capacities are maintained, and recycling activities are not adequately fostered. We, therefore, recommend research into policies and technologies for waste prevention, alongside the BA Green Deal achievements.

## 6.2 Implications for theory and methodology and limitations of Q-methodology

Scientifically, we aimed to contribute by briefly reflecting on the value and usefulness of the Q- method in BA application debates. The theory behind Q-methodology is that by finding different subjective viewpoints improvements in the governance of the 'messy' policy issue can be realised. We consider our study in this sense valuable also in this field of BA applications because agreement and disagreement among the experts could indeed be identified in a structured way, resulting in practical implications (see before). However, it should also be noted that applying the method is not straightforward and it has some limitations. A good-quality Q-method is very much dependent on the quality of the concourse of statements and the selection of experts. This makes the method time-consuming and not always easy to apply as was shown in this study that two respondents could not force their ideas into the Q-sorting frame. A very careful check on the statements in the concourse is paramount as well as involving a sufficiently wide number of respondents (to solve issues that some people cannot force their ideas in the frame) is paramount in successfully applying the Q-methodology. We recommend more research into the applicability of the Q-methodology in other countries (other cultures, other specific BA policies) to learn about the 'good use' of this methodology to bring (some) clarity in sometimes highly complex and fuzzy expert debates.

**Acknowledgements** We would like to thank all the reviewers for their efforts and time to review the manuscript. The valuable comments and suggestions were deeply appreciated and helped us to improve the quality of the manuscript.

**Author contributions** All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by GP. The first draft of the manuscript was written by GP and JAA. UP commented on several versions of the manuscript. All authors read and approved the final manuscript.

**Funding** The authors declare that no funds, grants, or other support was received during the preparation of this manuscript.

**Data availability** The datasets generated during and/or analysed during the current study are available in the TU Delft repository and can be found with this link: http://resolver.tudelft.nl/uuid:6bb92e8f-76f1-420a-8343-12bf27fedd8f.

## Declarations

**Conflict of interest** The authors have no relevant financial or non-financial interests to disclose.



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