Coping with Substances of Concern in a Circular Economy

RIVM letter report 2020-0049
M. Beekman et al.
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Colophon

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Monitoring and Evaluation Circular Economy

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Synopsis

**Coping with substances of high concern in a circular economy**

By 2050 the Dutch Government hopes to have a completely circular economy. An economy in which resources are continuously reused and with as little waste as possible. In a safe circular economy, risks to humans and the environment from hazardous substances in (recycled) materials are negligible. Substances of high concern, like those causing cancer for example, will only be used in materials and products when there are no known alternatives and their use is considered essential for the functioning of society. Substances of concern must not be released during production, use or re-use.

RIVM believes that this transition to a circular economy provides opportunities to deal with substances of high concern safely, and to monitor their use. It is just not easy. RIVM has investigated what is needed to achieve this transition safely and has identified three challenges. First it is essential to share information about the substances used, including substances of high concern, throughout the product chain. Second, all parties in the product chain must ensure that materials and products can be reused safely. Producers should think about this at the design stage of their products. Users, (waste) processors and governments should also contribute. Finally, it's important that everyone involved deals responsibly with the materials and products that contain substances of high concern for which there is no alternative.

Based on these three challenges, RIVM recommends possible actions for the short and longer term. For the short term, RIVM highlights the need to develop a policy vision and interim goals and to prioritise those products, materials and substances for which there is an urgent need to realise safe and circular product chains. These recommendations need to be developed further over the coming years and adapted to the rapidly changing demand for substances created, for example by technical innovation. Additionally, RIVM provides suggestions for monitoring whether reuse/recycling of substances of high concern during the transition to a circular economy is taking place safely.

It is hoped that this report will offer some guidance and help to set an agenda for further debate between governments, companies, NGOs and research centres. This is a debate on policy, science and the monitoring of substances of high concern during the transition to a circular economy. This report was commissioned by PBL Netherlands Environmental Assessment Agency.

**Keywords:** circular economy, substances of (very) high concern, chemicals, reuse/recycling, monitoring, (extended) producer responsibility, information, integral decision making
Publiekssamenvatting

Omgaan met zeer zorgwekkende stoffen in een circulaire economie

De Nederlandse overheid streeft naar een volledig circulaire economie in 2050. Hierin is er zo min mogelijk afval en worden grondstoffen steeds opnieuw gebruikt. In een veilige circulaire economie zijn de risico’s van schadelijke stoffen in (hergebruikte) materialen verwaarloosbaar voor mens en milieu. Stoffen met zeer zorgwekkende eigenschappen (ZZS), omdat ze bijvoorbeeld kanker veroorzaken, mogen dan alleen worden gebruikt in materialen en producten als er geen andere mogelijkheid bestaat en het product onmisbaar is. De ZZS mogen er niet uit vrijkomen, ook niet bij het hergebruik.

Volgens het RIVM biedt de overgang naar een circulaire economie kansen om veilig om te gaan met ZZS en het gebruik ervan in beeld te krijgen. Het is alleen niet makkelijk. Het RIVM heeft geïnventariseerd wat nodig is en heeft daarbij drie uitdagingen geconstateerd. Als eerste is het noodzakelijk om door de hele productketen informatie te delen over de gebruikte stoffen, inclusief ZZS. Als tweede moeten alle partijen in de productketen ervoor zorgen dat materialen en producten veilig kunnen worden hergebruikt. Producenten kunnen hier al bij het ontwerp nadenken. Gebruikers, (afval)verwerkers en overheden kunnen daar ook aan bijdragen. Ten slotte is het van belang dat alle betrokkenen verantwoord omgaan met materialen en producten met ZZS die niet te vervangen zijn.

Aan de hand van de drie uitdagingen doet het RIVM aanbevelingen welke acties op de korte en langere termijn mogelijk zijn. Voor de korte termijn benadrukt het RIVM het belang om scherper te stellen voor welke producten en materialen met voorrang veilige circulaire productketens moeten worden gerealiseerd. Daarnaast zou een beleidsvisie en met tussentijdse doelen moeten worden uitgewerkt. De aanbevelingen moeten de komende jaren verder worden uitgewerkt en worden aangepast aan de snel veranderende vraag naar stoffen door technologische ontwikkelingen. Ook reikt het RIVM mogelijkheden aan om verantwoord hergebruik van ZZS te monitoren tijdens de overgang naar een circulaire economie.

Deze verkenning is agenderend, en beschrijft aandachtspunten voor discussies tussen overheden, bedrijven, maatschappelijke organisaties en onderzoeksinstanties. Deze discussies gaan over beleid, onderzoek en monitoring van ZZS in een circulaire economie. De verkenning is in opdracht van het Planbureau voor de Leefomgeving uitgevoerd.

Kernwoorden: circulaire economie, zeer zorgwekkende stoffen, chemische stoffen, hergebruik/recycling, monitoring, (uitgebreide) producerentverantwoordelijkheid, informatievoorziening, integrale afweging
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Summary

The Dutch Government collaborates with businesses, community organisations, knowledge institutions and other public authorities to realise a circular economy (CE) in the Netherlands in 2050. In the envisioned circular economy, the amount of waste generated is minimal and raw materials are re-used over and over. In addition, the Netherlands aims to create a ‘non-toxic environment’: a safe living environment in which risks to health and environment are negligible, because hazardous substances are barred from the environment.

As long as national substances of concern meeting the criteria for REACH Art. 57 (zeer zorgwekkende stoffen, ZZS) are used in products and materials, these substances could re-enter the product chain in a circular economy. As a result, workers, consumers and the environment could unintentionally be exposed to these substances, especially when the new application is different from the original application. It is therefore crucial to know what will happen to ZZS when the products and materials are used in secondary or subsequent applications. In a safe circular economy, material cycling takes place in such ways that risks to humans and the environment due to hazardous substances are negligible. Substances that have ZZS properties will only be used in materials and products if there are no alternatives available and the product is deemed essential. It is crucial that ZZS are not released by these applications, not during use, nor in the phase in which these materials and products are cycled.

The Netherlands Environmental Assessment Agency (PBL) asked RIVM to indicate (a) the key focus areas in responsible handling of ZZS in combination with achieving closed loops in product chains (circularity) and (b) what possible first steps could be taken regarding ZZS in order to monitor this transition.

It is important to note here that this report represents an exploratory study, and could be viewed as a first step for further discussion about policy development and monitoring regarding this theme. Government authorities, businesses and community organisations are encouraged to continue thinking about the challenges outlined in this report. This report is intended to set the agenda, and not to outline a comprehensive overview of the issues involved. This report focuses specifically on ZZS, because handling these substances requires special care and attention due to their specific properties; for instance, they could cause cancer (carcinogenic), adversely affect reproductive capability (reprotoxic) or accumulate in the environment (persistent and bioaccumulative). However, many points in this report also apply to the use of other chemical substances.

This report identifies three major challenges:

1. Availability of information on ZZS in the supply chain
2. Expanding responsibility throughout the entire product chain
3. Safe handling of ZZS in a circular economy where phasing out is not possible (or no longer possible)
The first challenge involves the necessity to share information about substances throughout the entire production chain. In a circular economy, products and materials are introduced into the cycle again, including the ZZS they contain. To that end, it is crucial to have access to information across the product chain regarding the presence and safety of substances, including ZZS. At the moment, information is mainly available during the production phase, but is lost further down the chain.

It is then necessary for various parties in the chain to take responsibility for the safe use and re-use of substances, including ZZS, in materials and products. Manufacturers, for example, have a responsibility to design products so that they can be safely used and re-used depending on their predetermined application. But users and companies further down the chain also have a responsibility within a scenario for safe use and cycling and they must be enabled to take it.

Finally, ZZS are found in many products that exist today; it will not be easy to phase them all out, and may not even be possible. The final challenge is about responsible handling of ZZS in a circular economy where phasing out is impossible, or no longer possible. Within these ZZS, a distinction is made between:

a) 'Legacy': ZZS that are prohibited in new products but still present in products in circulation;

b) Essential uses: For certain applications – certainly in the short and medium term – ZZS are necessary because of their specific functionality and therefore cannot be phased out completely;

c) As yet unknown ZZS: harmful effects usually only become clear (long) after the introduction of new substances. As knowledge continues to develop, substances that are not yet a cause for concern may be classified as ZZS in the future;

d) Changes in the use of ZZS due to developments in society: as a result of the rapid development of innovations (but also due to changing requirements imposed by society), there are shifts in the demand for and supply of substances, including ZZS.

The report provides various practical examples of the three challenges, followed by an analysis of possible indicators and sources of information for monitoring ZZS in a circular economy. A distinction is made between process indicators and effect indicators. Some of these may be operational in the short term because they are based on information which is currently available. Other indicators call for the active collection of additional information that is currently not available anywhere (or only partially). In order to obtain a comprehensive picture of ZZS in a circular economy, it is important to start monitoring (wherever possible) and at the same time work on obtaining additional information that is not (yet) available.

Finally, based on a vision for 2050, recommendations are made for short-term (2020-2021), medium-term (2021-2030) and long-term (2030-2050) actions to achieve this vision. Actions will be categorised according to the challenges previously identified, accompanied by specific actions to monitor progress.
The transition to a circular economy, and the role ZZS play in that context, takes place in a complex and dynamic playing field with new substances, knowledge and technologies, shifting requirements for raw materials and other substances, and new policy intentions. For those reasons, it would be wise to see these recommendations for both policy development and monitoring as a starting point for a more widely discussed and supported agenda for research, monitoring and policy, and to periodically evaluate and adjust them as needed.
1 Introduction

The Netherlands aims to have completed the transition to a circular economy (CE) in 2050 [Rijksoverheid, 2019c]. In addition, the Netherlands aims to create a ‘non-toxic environment’ in which risks to health and environment are negligible, because substances of concern are barred from the environment [Ökopol, RIVM et al., 2017a; Ökopol, RIVM et al., 2017b].

Chemicals possess various properties and are therefore used in processes, materials and products, serving various functions. For example, they are used in pure form (e.g. by the chemical industry), in a mixture with other substances (e.g. in metal alloys, fuel, detergent and lubricants), as additives in a material, or as a building block (monomer) to create a polymer. These substances may be considered substances of very high concern (ZZS\(^1\)) due to their hazardous properties.

Chemical substances can pose risks; these risks emerge from a combination of the hazardous properties of a substance and exposure of humans and/or the environment to that substance. For example, exposure can occur during production and during or after product use. The exact exposure to a ZZS substance (and therefore the risk) depends on the application of the substance. This report focuses specifically on ZZS, because handling these substances requires special care and attention due to their hazardous properties; for instance, they could cause cancer (carcinogenic), adversely affect reproductive capability (reprotoxic) or accumulate in the environment (persistent and bioaccumulative). However, many points in the report also apply to the use of other chemicals, which do not have hazardous properties that are considered of very high concern, but may still pose risks to humans and the environment.

The Dutch economy is currently still largely linear, and most products are destroyed (incinerated) or landfilled after their functional use phase (‘end-of-use’). However, many developments are already taking place in the transition to a circular economy. Examples include the increasing use of separate collection and recycling, but also the emergence of new chemical recycling methods and the renewed focus on re-using and repairing products. The transition to a circular economy is taking place in a highly dynamic playing field. This offers new opportunities but can also give rise to new risks for coping with ZZS. For instance, new substance-application combinations are being developed (e.g. because of the energy transition), which may lead to new applications and therefore additional risks from ZZS. It is crucial for a safe circular economy to know what will happen to ZZS when products, parts and materials are used in a second (or subsequent) application (‘cycled’). This is particularly relevant if the new application is different from the original use. This might lead to new unintended exposure of workers, users and the environment to ZZS.

\(^1\) Chapter 2 offers a more detailed explanation of the term ‘ZZS’ (‘national substances of concern meeting the criteria for REACH Art. 57, referred to as ‘zeer zorgwekkende stoffen’, ZZS).
The transition to a circular economy requires a different approach to ZZS, and offers momentum to take a safer, more preventive approach to coping with ZZS and their risks. In a circular economy, manufacturers must develop clear ‘end-of-use’ scenarios for their products. They should take into account exposure to ZZS in subsequent applications. Responsible material recycling requires insight into what substances are used in products, and increases the importance of making responsible choices for substances during the design phase. Availability of information throughout the chain about substances in materials and products in general and ZZS in particular determines the possibilities for responsible recycling of the various materials. Insufficient information makes it necessary to place restrictions on material recycling, or even to destroy materials.

**Objective and project methodology**

The Netherlands Environmental Assessment Agency (PBL) asked RIVM to indicate (a) the key focus areas and steps to be taken for responsible handling of ZZS in combination with achieving closed loops in product chains (circularity) and (b) what possible first steps could be taken regarding ZZS in order to monitor this transition. Based on that, the main question of this report has been formulated as:

What are the main challenges for responsible handling of ZZS in (the transition to) a circular economy and what first steps can be taken to monitor ZZS in a circular economy?

This question is at the heart of this report, which is part of the Working Programme on Monitoring and Managing the Circular Economy 2019-2013 [PBL, 2019]. The project is part of WP 3, the Dutch Raw Materials Information System (Grondstoffen Informatie Systeem – GRIS).

To answer the above questions, this RIVM report provides:

- an overview of the main challenges where ZZS and CE intersect;
- an initial inventory of possible indicators for monitoring ZZS in a circular economy;
- recommendations for initial actions to address the challenges identified and steps to be taken to launch a monitoring strategy for ZZS in a circular economy.

The purpose of this report is to draw attention to ZZS in the transition to a circular economy. It is important to note here that this report is only an exploratory study. The report should therefore be seen as support for further discussion on policy development and monitoring regarding this theme. Governments, businesses and community organisations are invited to continue working on the challenges outlined in the report. This report does not attempt to provide a complete overview of the issues at hand, let alone offer an exhaustive list of solutions. Follow-up discussions on this theme should lead to a more comprehensive overview of the issues at hand and to the continued development of actions and possible solutions to deal with this problem, both in terms of policy and for the implementation of monitoring.

This report focuses on recycling raw materials and on associated (potentially) harmful exposures that affect human health and the
environment. Other themes such as environmental impact, prevention of litter and waste, the scarcity of and dependence on raw materials, use of renewable energy sources and raw materials, socio-economic factors and social perception are partly addressed in this report, but the report does not focus on these topics.

This report has been created in a relatively short period of time based on expert knowledge available within RIVM as well as input from an external advisory committee. We have relied wherever possible on the available sources on these themes, to the best of our knowledge. Since the main purpose of this report is to ensure that this issue is on the agenda, and we are not aiming to provide a comprehensive overview, we did not conduct extensive desk research for the purposes of this report. Therefore, external sources that could potentially be relevant within the theme of this report may not have been consulted. However, in order to broaden the RIVM perspective offered by this report, it was decided to ask a number of external experts to offer their brief reflections on this report; these reflections have been included in the report. This report has been written with the Netherlands as its starting point, but the discussion about ZZS and CE absolutely extends into the international arena.

**Reading guide**
Chapter 2 provides an overview of concepts, policy programmes, measures and developments concerning ZZS in a circular economy. Chapter 3 provides a theoretical exploration of coping with ZZS in a circular economy and describes the most important challenges (in our view), illustrated by examples. The insights gained in Chapter 3 help to identify possibilities for monitoring in Chapter 4. Chapter 5 then presents the key recommendations. This report ends with a conclusion and afterword in Chapter 6 and a number of short reflections by external experts in Chapter 7. The report closes with a brief word of thanks in Chapter 8.
2 Definitions and policy frameworks

2.1 Substances of Very High Concern and ZZS

Definitions

The identification of ZZS (‘Zeer Zorgwekkende Stoffen’ in Dutch) is laid down in the Environmental Management Activity Decree [Wettenbank Overheid, 2019]. This decree states that the criteria for ZZS are derived from Article 57 of the REACH Regulation [ECHA, 2019e]. Substances with one or more of the following hazardous properties meet these criteria and are therefore considered ZZS in the Netherlands [RIVM, 2019b]:

- Carcinogenic (C)
- Mutagenic (M)
- Reprotoxic (R)
- Persistent, bioaccumulative and toxic (PBT)
- Very persistent and very bioaccumulative (vPvB)
- Equivalent Level of Concern for human health or the environment (for example due to endocrine-disrupting properties)

Companies that put chemical substances on the market are responsible for checking whether the substances they use meet the ZZS criteria. This means that there is no exhaustive list of ZZS. However, RIVM has compiled a list of known ZZS as a guide. This list is based on various international laws and treaties. This list of ZZS is updated twice a year and currently contains approximately 1400 substances [RIVM, 2019c].

The European Union maintains a list of ‘Substances of Very High Concern’ (SVHC) [ECHA, 2019a]. These SVHC are subject to the same criteria as the substances on the Dutch list of ZZS. The difference between the SVHC list and the Dutch ZZS list is that the European list is established by the European Chemicals Agency (ECHA) on the basis of a proposal for inclusion of a substance on the list; these proposals are submitted by EU Member States or by ECHA. This is a process that takes a number of years. A number of substances are added to the SVHC list every year. There are currently about 200 substances on the SVHC list. These substances are, of course, all on the Dutch ZZS list as well.

Potential ZZS (pZZS) are substances that may potentially meet the ZZS criteria but have not yet been identified as ZZS. This may be because certain information is missing or because the evaluation of the available information has yet to take place. RIVM was commissioned by the Ministry of Infrastructure and Water Management to compile a pZZS list as a tool for the competent authorities. It consists of an exhaustive list based on developments within the REACH framework arising from policy concerns about the use or properties of a substance. The list of potential ZZS comprises some 350 substances [RIVM, 2019d]. RIVM also updates the pZZS list twice a year.

ZZS can be used in production processes, in products or parts of products, and in materials. For convenience, this report uses the terms ‘products and materials’ in relation to the use of ZZS. For this purpose,
products refer to the terms ‘articles’ and ‘mixtures’ as defined in REACH. Sometimes, in addition to products and materials, the definition will also be expanded to explicitly mention certain processes or parts. Even where this is not explicitly stated, a broader application of this terminology may be relevant. Box 1 offers an indication of the extent of the use of ZZS based on production and use volumes.

**Box 1**: Approximate production and use volumes of harmful substances in the EU

In Europe, all substances produced, used or placed on the market in excess of 1 tonne per year must be registered with the European Chemicals Agency (ECHA). These registrations must indicate the hazardous properties of the substances. It should also include a very rough indication of tonnage. ECHA reported in 2014 that 512 of 1312 known CMR substances had been registered [ECHA, 2015]. This means that 40% of the substances with a harmonised CMR classification under the CLP Regulation [ECHA, 2019b] are produced, used or placed on the market in Europe in quantities above 1 tonne.

In addition, Eurostat collects information on the production and use of chemicals in the EU [Eurostat, 2018]. Primary attention is on substances that are hazardous to humans and the environment. Production of these (hazardous) chemicals in the EU is mainly situated in Western Europe. Eurostat uses the CLP classification as a basis for classifying substances as ‘harmful’. This includes more substances than just the substances on the ZZS list. This includes substances that are, for example, acutely (highly) toxic to humans or the environment, or can cause organ damage. Acute toxicity and organ damage are not ZZS criteria on their own, but they are in combination with the properties of persistence and bioaccumulation (PBT is an abbreviation of persistent, bioaccumulative and toxic). The CMR substances presented by Eurostat are all ZZS, however.

The proportion of substances harmful to the environment is about 30% of the total volume of substances produced. For substances harmful to human health, this percentage is considerably higher: around 75%. This means that about three-quarters of the total substances produced in the EU (in the order of 250 million tonnes per year) are ‘harmful’ according to the CLP classification. The volume of CMR substances produced in the EU is around 30-40 million tonnes per year. This CMR production volume hardly changed between 2004 and 2017, representing around 14% of the total volume of substances produced in the EU. A more or less comparable percentage and volume applies to the CMR substances used in the EU. Eurostat does not separately identify PBT substances in its analyses.

Eurostat does not provide information on how the 30-40 million tonnes of CMR substances mentioned above are distributed among the individual CMR substances in combination with their applications (processes, products and materials). A significant proportion of CMR substances are used as intermediates; these substances do not ultimately end up in (consumer) products and materials. It is therefore difficult to achieve a clear and comprehensive overview of the scope of the flow of ZZS in products and materials or in production processes,
which may pose a problem in a circular economy (and the transition in that direction). It is clear, however, that large production and use volumes are expected (both in Europe and in the Netherlands), and moreover do not show a declining trend in 2004-2017. The Eurostat overviews also clearly show that this issue extends beyond ZZS; other harmful substances (such as acutely toxic substances or substances that can cause organ damage) also require attention along the way to a safe circular economy.

**ZZS policy**
The Dutch government has made it a priority to address ZZS. Humans and ecosystems can come into contact with ZZS via the environment (e.g. via air, water or soil), food, the workplace or through products. ZZS policy is focused on keeping ZZS out of the living environment, while reducing emissions as much as possible (the minimisation obligation under the Activities Decree [Wettenbank Overheid, 2019]). This source-based approach could encompass various measures. This includes substitution of ZZS with safer substances as well as organisational and technological changes. If a source-based approach is not possible, other measures should be taken to further reduce emissions.

In addition to the minimisation obligation, a number of international frameworks also promote source approaches and minimisation of exposure to substances of concern:

- Substitution of certain substances by less hazardous substances or techniques. This is done by means of restriction (for substances posing a risk to humans or the environment) and authorisation (for SVHC substances) in REACH and in global agreements such as the Stockholm Agreement [United Nations Environment Programme, 2019];
- European restrictions on use in specific applications (e.g. in toys [ECHA, 2019d; European Parliament and Council, 2012] or electrical appliances [European Parliament and Council, 2011]);
- The European regulatory framework dictates that certain substances of concern (e.g. carcinogens) are in principle banned from authorisation as plant protection products [European Parliament and Council, 2009] or biocides [European Parliament and Council, 2012];
- Incentivising innovation, resulting in the use or emission of substances that are less hazardous.

The aim of the policy on potential ZZS is to take precautions, for example by conducting further research or by limiting emissions of these substances [InfoMil, 2019a]. The list of potential ZZS is intended as an aid for competent authorities and companies.
2.2 Circular Economy

**Definitions**

In 2016, the Dutch Cabinet published the government-wide Circular Economy Programme [Ministerie van Infrastructuur en Milieu & Ministerie van Economische Zaken, 2016]. A ‘circular economy’ (CE) is defined in the programme as follows:

"In 2050, raw materials will be used and re-used efficiently, without harmful emissions to the environment. To the extent that new raw materials are needed, they are extracted in sustainable ways and further damage to the social and physical environment and to health is prevented. Products and materials are designed in such a way that they can be re-used with minimal loss of value and no harmful emissions to the environment."

The government-wide programme identifies sectors and raw material chains that will be given priority within the transition to a circular economy. These chains are divided into five transition agendas: **biomass and food, plastics, manufacturing, construction** and **consumer goods**.

The R-strategies (Figure 1) provide a system framework that divides the circular economy into a hierarchical ladder with different steps for more efficient use of raw materials. As a rule of thumb, higher R-strategies are preferred.

*Figure 1: R-strategies for material cycling [Potting, Hanemaaijer et al., 2017]*

Within the R-strategies, steps R3-R7 are particularly applicable for service products: raw materials that do not wear out or are hardly *consumed* during use. Using mechanical or chemical processing, these
products can be put back into circulation in what we call the technosphere. This technosphere is particularly relevant to the transition agendas for **plastics, manufacturing, construction** and **consumer goods**.

Products that are *consumed*, wear out or deteriorate significantly as a result of their application will inevitably end up in the biosphere, including the ZZS present in those products. This includes cleaning agents, cosmetics, fertilisers, crop protection products, but also the outer layer of car tyres. Strategies R3-R7 are less applicable in that context (or not at all), but this does not mean that these products have no role in a circular economy. Products that will inevitably end up being consumed should be designed to (eventually) biodegrade safely in biological systems, thus creating new raw materials for biological systems; if this does not occur, these systems will be polluted. The safe return of materials to the biosphere is mainly relevant to the transition agendas for **biomass and food** and **consumer goods**.

In the linear economy, a typical product chain generally has three phases: production, use and waste. In a circular economy, this will transition into production, use and safe re-use (including recycling into raw materials for new products) [Ministerie van Infrastructuur en Milieu & Ministerie van Economische Zaken, 2016]. There is no circular economy at this point. The current situation can better be described as a linear economy in which material re-use takes place on an ever-increasing scale, but in which there is also still large-scale new extraction of raw materials, net imports of products and materials, and removal or contamination as waste: a partial re-use economy (Figure 2).

![Figure 2. Visual presentation of the transition from a linear to a circular economy. Translated by RIVM [Ministerie van Infrastructuur en Milieu & Ministerie van Economische Zaken, 2016].](image)

It is not realistic to make all products and production processes fully circular from one moment to the next. In addition, this involves products that are already in circulation and are by and large not designed to be re-used (safely). Creating a safe circular economy on a large scale requires innovation and change in the field of technology as well as in business models. The period in which the mainly linear practice...
gradually turns into a situation in which materials are safely re-used on a large scale is referred to as the transition to a circular economy.

**CE policy**
The government-wide Circular Economy Programme lists the ambitions, stating broad objectives for the short term, for 2030 and for 2050. In 2050, all raw materials will be used and re-used efficiently, with no harmful emissions that affect humans or the environment. An interim target has been set for 2030: a 50% reduction in the use of primary raw materials (mineral, fossil and metal). The Circular Economy Implementation Programme 2019-2023 [Ministerie van Infrastructuur en Waterstaat, 2019] was drafted for implementation of the CE ambitions within the short term. The implementation programme presents concrete activities in the public and private sectors that serve as new steps, incentives, illustrations and inspiration for the transition to a circular economy during the 2019-2023 period. These activities may be linked to the five transition agendas, but the programme also deals with themes that are related to several agendas.

The Working Programme for Monitoring and Managing the Circular Economy 2019-2023 [PBL, 2019] was developed to monitor progress on the transition to a circular economy according to the government-wide Circular Economy Programme and the Implementation Programme. This monitoring programme has been set up to provide insight into the extent to which the set objectives are being achieved in policy and to provide options for possible adjustments.

**Waste policy**
The current National Waste Management Plan (LAP3) is the policy framework for waste in the Netherlands [Rijkswaterstaat, 2019a]. LAP3 compares the objectives of policies on substances and waste management in a circular economy and concludes that:

>a balance must be found between promoting recycling on the one hand and reducing the amount of hazardous substances in the economy on the other. In the European discussion on recycling of materials containing ZZS, the Netherlands believes that a methodology must be formulated at the European level to determine the best option (B.14.4.1).”

LAP3 uses a risk-based approach to determine the cases in which recovery and re-use of waste containing ZZS may be permitted.

### 2.3 Safe & Circular by Design

Safe by Design is the concept in which safety is an integral, early part of a design aimed at sustainable products and processes.

>Safe-by-Design means that the safety of materials, products and processes for humans and the environment is already taken into account as much as possible in the design phase. This is precisely when crucial choices must be made about raw materials, basic techniques and applications. Safe-by-Design aims to take these aspects into account at the earliest stage of research and development. This therefore requires (new) safety awareness on the part of scientists as well as process and product developers, but also on the part of the management of
companies making investment decisions. Developing a strategy to achieve a non-toxic environment is in line with this. This often involves the design of non-toxic or perhaps even non-chemical alternatives to certain toxic substances.” [Ministerie van Infrastructuur en Waterstaat, 2018]

The Ministry of Infrastructure and Water Management defines Safe by Design on the basis of a programme of the same name [Ministerie van Infrastructuur en Waterstaat & RIVM, 2019]. This also places a strong emphasis on the connection to CE. By emphasising both aspects (Safe & Circular) from the design phase onwards, the principles can reinforce each other. A product that is designed according to the Safe by Design principle can be safely used (again) in a circular economy. Moreover, if this product is designed with recyclable and separable materials, it provides an additional incentive for recycling the (safe) materials. For that reason, this combination is attracting more and more attention internationally, including in the business world [Ellen MacArthur Foundation & Cradle to Cradle Products Innovation Institute, 2018].
3 Challenges involving ZZS in a circular economy

3.1 Introduction

The previous chapter briefly defined the terms ZZS, circular economy (CE), Safe by Design and Circular by Design, and described the various policy programmes. It was already clear that these concepts are strongly interlinked and that measures taken in one context can have an effect in another context. In today’s (linear) economy, the use of ZZS may already lead to environmental and health risks. In a circular economy, safe handling of ZZS will become more complicated because materials and products will be re-used in different ways, possibly leading to new exposure routes. In this section, we illustrate these possible changes in exposure (see Table 1) and discuss two extreme scenarios for dealing with ZZS and the circular economy. We then successively formulate what we believe are the three most important challenges for dealing with ZZS in a circular economy. Finally, we discuss the need for integral considerations about the use of ZZS in a circular economy.

Changing risks of ZZS in a circular economy

Section 2.2 presented the R-strategies for use and re-use of materials. The R-strategies describe ten ways to reduce the use of materials or to re-use materials. These strategies may influence the use and possible risks of ZZS. Table 1 gives examples of changing exposures to ZZS by applying these strategies. In some cases, this may also lead to new risks. This table is intended as an illustration and does not aim to provide an exhaustive overview.

Table 1. Illustration of how inherent ZZS risks can change through the implementation of different R-strategies.

<table>
<thead>
<tr>
<th>R strategy</th>
<th>Possible change in risks of ZZS</th>
</tr>
</thead>
<tbody>
<tr>
<td>R0 Refuse</td>
<td>This strategy leads to reduced use of raw materials because a product’s function is provided in a different way or arranged using a non-chemical solution, or may even no longer be offered. As a result, ZZS in these materials are also automatically used less, for example switching to biological instead of chemical crop protection measures, and providing digital invoices instead of printed receipts.</td>
</tr>
<tr>
<td>R1 Rethink</td>
<td>Using materials and products in other ways could make it possible to intensify their use. Take car-sharing, for example. This change can lead to additional risks due to increased wear and tear of materials with ZZS.</td>
</tr>
<tr>
<td>R2 Reduce</td>
<td>By making the same product with fewer raw materials and other materials (material efficiency), it may also lead to a reduced use of ZZS. On the other hand, it could also lead to additional use and new risks if the same functionality is maintained by applying additional ZZS.</td>
</tr>
<tr>
<td>R strategy</td>
<td>Possible change in risks of ZZS</td>
</tr>
<tr>
<td>------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>R3 Re-use</td>
<td>Re-use will result in fewer new products and therefore a reduced use of ZZS for new (virgin) materials. However, prolonged use of a product may be associated with higher exposure to ZZS, e.g. if materials wear out more than in a situation without re-use, or if products containing ZZS are re-used that are no longer permitted in new products.</td>
</tr>
<tr>
<td>R4 Repair</td>
<td>Similar to R3, with the addition that new or different ZZS may be required to repair, refurbish or replace parts. It may be possible that this will require smaller quantities than required for the production of a new product.</td>
</tr>
<tr>
<td>R5 Refurbish</td>
<td>Parts are re-used in a product with a different application. In general, this was not taken into account in the original design and the risks may be different in this new application. Knowing about the presence of ZZS is essential (other type of exposure/wear) to control ZZS risks.</td>
</tr>
<tr>
<td>R6 Remanufacture</td>
<td>Knowing about the presence of ZZS is also essential in recycling materials and raw materials, for example because materials may be recycled in other applications, resulting in possible unwanted exposure. It determines the quality and possibly the risk of applying it in the new product cycle. Rubber granulate on synthetic turf fields is a practical example of applied recycling in which the risks to humans and the environment were re-evaluated, because the new application changes the extent to which humans and the environment are exposed to the materials. This is clarified further in Box 2.</td>
</tr>
<tr>
<td>R7 Repurpose</td>
<td>Recovering energy from materials may lead to emissions of ZZS. Incineration releases emissions into the air, and emissions to soil or groundwater can take place via digestate as fertiliser (after biogas production). Knowledge about the presence of ZZS is therefore essential. Whether the ZZS emissions turn out differently in a circular economy depends on whether the current situation is different from R9. In many cases, R9 is already the current practice.</td>
</tr>
</tbody>
</table>
Box 2: Practical example: rubber granulate on synthetic turf fields

Promoting CE will result in the use of other (new) uses for materials. A well-known example is the use of old car tyres as infill on synthetic turf fields. A car tyre contains hundreds of chemical substances including various ZZS, such as various polycyclic aromatic hydrocarbons (PAHs) and bisphenol A. These substances are also contained in the rubber granulate made from these tyres and can be released from them, leading to exposure of humans and the environment to these substances. RIVM has investigated the possible risks for (amateur) athletes and the environment [Oomen & Groot, 2016; Verschoor, Bodar et al., 2018]. These studies show that environmental risks can occur in the immediate vicinity of synthetic turf fields with rubber granulate infill, but that the human health risks from playing sports are virtually negligible. Despite this, the presence of various ZZS and other hazardous substances in the granules continues to lead to scientific and social discussions about the risks to athletes. For example in the scientific discourse: a number of scientists have different – more stringent – views on the starting points and assumptions to be used in risk assessment. They believe that the precautionary principle should be applied due to uncertainties in the risk assessment. Moreover, this form of material cycling applied to old car tyres does not fit into a fully circular economy. Some of the granules end up in the biosphere, which means that they cannot be cycled repeatedly in technical loops and do not biodegrade (see 2.2). This not only leads to the release of substances from the granules, but plastic particles (microplastics) also end up in the environment.

A circular economy is often associated with recycling or other forms of re-use, in which materials are cycled over and over in controlled technical loops. However, as indicated in Section 2.2, ZZS can also play a role in more open applications in the biosphere. Some of these applications are discussed here separately to explain this aspect more explicitly. Materials (including ZZS) entering the biosphere can lead to risks, for example due to increased wear and tear or if biodegradable materials containing ZZS are used. In a safe circular economy, these materials must be designed so that they can be safely ‘cycled’ in biological systems. This means that these substances must be able to be incorporated into the biological cycle. This is currently often not the case, leading to contamination of the biological systems and environmental exposure to ZZS. Examples include:

- The use of additives in the production of biodegradable plastic; a base polymer may for instance be safe for biological systems, but ZZS may still be present in the added colouring agents, stabilisers, or other additives, which, due to application or disposal (e.g. via compost), also end up in biological systems;
- The use of different medicines may lead to ZZS in the wastewater. If products are subsequently made from that wastewater, such as struvite (phosphate mineral), there is a possible risk due to the presence of (ZZS) drug residues in those products;
- The use of pesticides that leave residues in the soil, leading to a deterioration in soil quality;
• Consumer goods such as cosmetics and detergents, which are consumed during use due to their purpose, and thus inevitably end up in the biosphere, although safe biodegradability is often impossible in biological systems.

**Hypothetical scenarios for coping with ZZS in a circular economy**

The examples in Table 1 show that a circular economy can lead to a different use of ZZS, which can lead to different exposure scenarios (and therefore inherent risks of ZZS). How the inherent risks of ZZS in a circular economy actually play out is also determined by policy measures that are taken to move towards a circular economy as well as policy measures that are taken to control ZZS risks (and interactions between such measures). We illustrate these changing risks based on two hypothetical scenarios in which the government implements certain (radical) measures related to ZZS and/or CE. Working out the scenarios provides a better overview of the challenges involved in coping with ZZS in achieving a fully circular economy.

Hypothetical scenarios:

1. **Achieve 100% re-use and recycling of materials and products as quickly as possible.** In this scenario, all materials and products are used again and again. The use of new materials is thus minimised. As a consequence, ZZS currently present in materials used today will end up in new products and will therefore continue to be recycled. This is not aligned with the policy objective to prevent the use of ZZS as much as possible or to replace them with safe alternatives. In addition, society's demand for materials and products will not remain the same in the future; demand changes constantly as a result of developments and innovations. Materials that were important in the past may not be in the future. Take for instance the use of lead in cathode ray tubes in old televisions. Flat-screen televisions do not need to use cathode ray tubes, which means that the leaded glass needs a new application. Conversely, the demand for ZZS may also increase due to changes in society, such as the growing demand for materials for the energy transition (see Box 7 for a practical example about lithium-ion batteries). This cannot be fully met with what is released from existing products, which may increase the demand for new ZZS.

2. **All new materials and products put on the market are free of ZZS as soon as possible and are designed according to the Safe by Design principle.** The most important question (or bottleneck) in this scenario is: what will happen to materials and products currently in circulation (including the ZZS in this scenario)? Materials or ZZS that are no longer allowed in new products but are still in circulation are considered ‘legacy’ materials. If these materials are not allowed to be put back into circulation (or only after removal of ZZS), the amount of ZZS currently in circulation in society will decrease relatively quickly (although this will be slower for materials with a long use phase). On condition of course that during the waste or re-use phase, a distinction can be made between ‘clean’ products and products with ZZS.
However, this will certainly lead to a limited level of re-use and recycling in the short and medium term. If these legacy materials are cycled over and over without removing the ZZS, those substances will remain in the system. Restricting the use of existing materials will mean less circularity and more loss of materials. Furthermore, it is uncertain whether it is possible to create a Safe by Design alternative for all applications. For some applications, ZZS may continue to be needed, because the application is indispensable to society and no safe alternatives are available (essential uses\(^2\)). Finally, there will also be substances in the future that will receive ZZS status as new information becomes available. In other words, we will regularly be confronted with new ZZS in the future, including the question of whether the material or product containing it can still be re-used.

The scenarios above teach us that responsible handling of ZZS, initiatives to promote material cycling, or safe design of new products do not always automatically combine well. The implementation of measures can have both positive and undesirable effects for the circular economy as well as for coping with ZZS. The trick is to look for the optimal interaction of measures to achieve policy goals for both ZZS and CE. In the following sections, we will discuss the main challenges involved in responsible handling of ZZS in a circular economy. We illustrate these challenges using a number of practical examples. The various challenges are closely related and partly overlap.

### 3.2 Challenge 1: Availability of information on ZZS in the supply chain

There are many ZZS and they are used in many products (in large and small quantities and often several ZZS at the same time). Because of the open economy and the import of many products from the EU and abroad, ZZS travel all over the world. Product chains are complex and involve many different stakeholders in the phases of production, use, and waste or re-use. For example, ‘production’ is usually not carried out in one step; rather, substances and materials go through different steps (e.g. formulation, mixing, component production and product assembly). In a circular economy, a material or product goes through several cycles (possibly in different applications) and there may be intermediate repair steps. This type of interaction and feedback makes the system more complex.

By recirculating materials with ZZS, new exposures and thus risks to humans and the environment may emerge. Knowledge about the presence of ZZS in materials and products is therefore necessary in order to make informed choices about safe re-use of materials and products. In fact, because ZZS is a dynamic concept (existing substances can still be discovered to be ZZS), and there are other substances besides ZZS that can have harmful properties, information on complete compositions of materials and products would ideally be

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\(^2\) In Section 3.4, we will go into more detail on the concept of essential uses.
available for a complete assessment. This often involves confidential and business-sensitive information, making it unattractive or even impossible for producers to be fully transparent about their compositions.

Some of this information is available at the beginning of the chain, partly due to obligations imposed on producers and importers at national and European levels. However, this information generally focuses on a select group of substances (e.g. SVHCs from REACH, which only comprise part of the ZZS list). Moreover, the duty to inform other stakeholders in the chain about the presence of these substances is often only in force at a specific concentration in the material or product. This means that sometimes information about ZZS is not available at all (missing knowledge). The (uncontrolled) import of products via internet retailers is a point of concern in this respect. In addition, the information regarding a material or product through the entire chain is often not passed on in practice, partly due to the complexity of the chain. Another complicating factor is that materials and products containing ZZS are often collected in mixed-category flows after use. As a result of all this, knowledge regarding substances used in materials and products is often lost somewhere in the chain, sometimes even before the use phase of a product, if not in the waste phase and processing for purposes of re-use and recycling [European Commission, 2018; Schoenmakere, Hoogeveen et al., 2019; Wachholz, Arditi et al., 2017].

There are various databases and reports that provide information on different types of substances for different actors and at different points in the product chain. However, in the current situation there is no conclusive overview of ZZS in product chains in the economy, and the risks they may cause. For a safe circular economy, it is necessary to ensure that information about ZZS becomes and remains more easily available throughout the entire chain, for example:

- Developers (R&D)/designers/producers/assemblers working on the production of safe and circularly designed products;
- Purchasers/users/owners who want to use (circular) products safely and offer them for re-use and recycling;
- Dismantlers/wreckers/recyclers/others who want to ensure safe material or product re-use;
- Competent authorities (such as licensing authorities and supervisory authorities) that actively monitors and controls the entire chain of production, use and re-use of materials and products.

This means that it is not sufficient in a safe circular economy to only have access to information about substances and the safety of substances, including ZZS, during the production phase. This information is also needed for safe use and re-use, and must therefore remain available throughout the chain. The large number of ZZS makes it very difficult in practice to have a full overview of all ZZS in circulation when transitioning to a circular economy. The practical example about ZZS in licensing (Box 3) offers an impression of the complexity involved in providing access to information about ZZS. It is important during the transition to take steps to make information about ZZS more readily available. Making all product chains fully transparent in one go is
impossible, but there is already a lot to be gained by focusing first on priority sectors, product chains, materials or substances: the 'low-hanging fruit'.

Box 3: Practical example: ZZS in licensing
In order to gain more insight into emissions of ZZS, the province of South Holland started to request information about these emissions from companies in 2017. This initiative was followed by the other provinces and by the Directorate-General for Public Works and Water Management (Rijkswaterstaat). On behalf of the Ministry of Infrastructure and the Environment, RIVM collects data on ZZS emissions into air and water, compiling them from these requests for information. This is used to create an overview of the current ZZS emissions by companies in the Netherlands. This not only includes emissions of ZZS used by companies; it also concerns ZZS formed as a result of the production processes. In response to the question, various sectors (including e.g. waste processors and companies in the oil and petroleum industry) have indicated that there are bottlenecks in providing the requested data. These problems mainly concern mixtures (sometimes of partially unknown composition or varying composition) and mixed flows of products, since their exact composition is unknown. Some industries also have data confidentiality issues; the exact composition of their product is competition-sensitive information and ZZS may be part of this. The (partial) absence of information on the presence of ZZS in (mixtures and mixed flows of) products makes it difficult for the company to provide information on ZZS emissions and for the competent authority to verify the accuracy of the information provided.

3.3 Challenge 2: Expanding responsibility throughout the entire product chain
Various stakeholders (companies, governments and users) have a responsibility when using ZZS (and other substances) in materials and products, but are often unable to take it or have to deal with conflicting interests. In order to achieve a safe circular economy, it is necessary for all parties in the chain to take their responsibility. This starts with producers who have to take into account safe material and product cycling after the use phase, incorporating that concept from the design phase onwards. Safe & Circular by Design plays an important role here (for new products). Providing correct and complete information to users and processors and establishing partnerships to achieve the intended end-of-use scenarios (for existing and new material flows) are also part of this. Product design and the provision of information by producers (or importers) must be arranged in such a way that stakeholders further down the chain can also take responsibility for the safe handling of ZZS in the use and processing of materials and products.

Various initiatives have already been taken in the Netherlands for Extended Producer Responsibility (EPR) for a number of product groups. Examples include plastic packaging (Packaging Framework Agreement II), electronics (Wecycle) and car batteries and tyres. In addition, there are various voluntary initiatives in which producers (want to) take responsibility for the end of the use phase, for example for mattresses.
(explained in more detail in Box 4), building façades [Rijksdienst voor Ondernemend Nederland, 2016], or jeans [MUD-Jeans, 2019].

**Box 4: Practical example: circular mattresses**

A variety of materials are generally used in mattresses, which are often irreversibly bonded and may also contain different ZZS (e.g. brominated flame retardants). That makes these types of mattresses unattractive for recycling purposes, which means that they often end up in a low-grade application or even in the incinerator. When safe material choices and options for recycling are taken into account in the design phase, it becomes easier to actually ensure these products go back into the cycle. For example, a mattress and bed manufacturer has increased its responsibility in the chain by partnering with suppliers to use reversible adhesives in product design. That makes it possible to separate out different materials. The company has also engaged in partnerships with logistics partners, found recyclers for the individual materials, and introduced new business models (lease structures) in order to ensure safe, high-quality product recycling actually takes place [Auping, 2018]. Where each party in the chain once only took responsibility for their own link (and nothing beyond that), a different situation is now starting to emerge. Aligning product responsibility with the stakeholders in the chain leads to gradual convergence of safe and circular production, use and re-use. The Circular Economy Implementation Programme 2019-2023 is working with policy-makers, researchers, entrepreneurs and consumers on achieving circularity in the mattress chain, indicated by means of an icon on mattresses.

Although much depends on the design phase of products, there is also much to gain at the end of the use phase. For example, when reusing products and materials (such as in the case of recycling), it is important that sufficient attention is paid to identifying, separating, tracing and removing and/or destroying ZZS from material flows. This is particularly relevant for (mixtures of) ZZS in existing material flows, where, for example, the desire to plan for high-quality recycling after the use phase of the product has not yet been taken into account in the design phase. Developing new and improved techniques for the identification of ZZS in material flows and their removal and/or destruction not only leads to safer and more valuable secondary materials from existing applications, but also broadens the possibilities that producers have to design safe products that are eligible used for high-quality recycling.

The Dutch Government also has a responsibility here: it can facilitate desirable developments in chain responsibility by adopting legislation in line with this goal and at the same time launching realistic transitional measures. In addition, government authorities can promote best practices by setting a good example in their own procurement policies.

### 3.4 Challenge 3: Safe handling of ZZS in a circular economy where phasing out is not possible

Although the aim is to replace all ZZS, and it is possible to take important steps in that direction, it is not realistic to aim for completely phasing out these substances in the short, medium and long term. ZZS are present in many places in our current society, and there are several
reasons why phasing out is not easy; this means that we will have to deal with them in some way for the time being. We can group the various reasons for the presence of ZZS into four categories:

a) ‘Legacy’: by focusing strongly on Safe & Circular by Design in the design phase, and by banning ZZS as much as possible in new products, the influx of new ZZS can be reduced. This does not alter the fact that ZZS are present even now in products that are still in circulation. Phasing out ZZS requires responsible handling of legacy materials and the ZZS in those materials, also because ZZS concentrations in recycling flows may increase over time (due to accumulation). Removing ZZS from these flows is the obvious solution, but it is not always technically or economically feasible and may lead to new risks or environmental impacts (such as increased energy consumption).

b) Essential uses: ZZS may be created unintentionally during a process, and it is not always possible to prevent them from forming. However, in many other cases ZZS are used because of their functionality, and phasing out the ZZS will require replacing it with safer alternatives. In some cases, it is uncertain whether there are safe(r) alternatives or not, or if it is possible to prevent the creation of ZZS during production. In those cases, phasing out one ZZS substance may result in a switch to another ZZS (referred to as ‘regrettable substitution’). There are examples of ZZS where the functionality of the substance is inherently linked to its harmful properties. An example of this is terphenyl hydrogenated in heat transfer fluids (see Box 5). Choosing to phase out this substance may also result in phasing out a specific product. The question in such a situation will be whether this product is necessary (essential) and whether, in a broad sense, alternative materials or techniques are available.

The Montreal Protocol (in which agreements were made on phasing out substances that deplete the ozone layer) defines the term ‘essential use’ for this specific group of substances [United Nations Environment Programme, 2016]. Important elements of this definition include:

- The substances are necessary for health or safety or are critical to the functioning of society; and
- There are no technically and economically feasible alternatives or the alternatives are unacceptable from an environmental or health perspective.

**Box 5**: Practical example: terphenyl hydrogenated in heat transfer fluids

An example of a substance whose harmful properties are inherently linked to its functionality is terphenyl hydrogenated. This substance is used in heat transfer fluid (HTF) systems, mainly in industrial and professional applications at high temperatures (above 300 °C). These HTF systems have many industrial applications, such as in the production of plastic (PET), in aluminium production and in the production of renewable energy from biomass. The HTF systems are in principle closed systems and the fluid has to be replaced approximately every sixteen years. The high temperatures that occur in the systems require the substance to be extremely stable, since the substance
will otherwise decompose quickly in the system and need to be replaced much more often. Possible alternatives to terphenyl hydrogenated, for example, should be replaced every two to four years and have similar hazard properties. There is a chance that a ban will result in a switch from one ZZS substance to another (‘regrettable substitution’). The required properties of these substances are also properties that give the substances their ZZS status. This is to be expected when the ZZS properties of a substance are so strongly related to its functionality and the discussion about essential uses becomes relevant.

c) As yet unknown ZZS: harmful effects usually only become clear (long) after the introduction of new substances. Due to the development of new knowledge about the properties of substances, substances that are not yet a cause for concern may be classified as ZZS in the future. This gradually creates a new legacy of ZZS which we are currently not aware of. More information is provided in the practical example about PFAS (Box 6).

**Box 6: Practical example: PFAS**

PFAS stands for poly- and perfluoroalkyl substances. These are man-made substances that do not occur naturally in the environment. PFAS have useful properties: among other things, they repel water, grease and dirt. They are found in various products, including lubricants, food packaging materials, fire extinguishing foams, non-stick coatings on pans, clothing, textiles and cosmetics. They are also used in various industrial applications and processes. It is not known exactly how many different man-made PFAS there are. The Organisation for Economic Co-operation and Development (OECD) has determined that there are over 4000 PFAS, but there may be more [OECD, 2018]. A number of substances from the large group of PFAS are known to have ZZS properties. Examples are PFOS (perfluorooctane sulfonic acid) and PFOA (perfluorooctanoic acid). These are ZZS because they do not break down in the environment (persistent), they accumulate in the human body and in animals (bioaccumulative) and they can cause harmful effects in humans and the environment (toxic), and are therefore classified as PBT substances.

Due to their harmful properties, there has been a significant reduction in the use of PFOS and PFOA. PFOA was used in the Netherlands to produce e.g. non-stick coatings on pans. By now, this substance has been replaced by so-called GenX substances. These GenX substances were believed to be less bioaccumulative and toxic than, for example, PFOS and PFOA. More and more information is becoming available about GenX substances. The current information shows that these substances are persistent, mobile (spreading rapidly through the environment) and toxic; in June 2019, ECHA decided to designate these substances as SVHC (thus also conferring the ZZS designation in the Netherlands) [RIVM, 2019a]. This shows that the ZZS concept is not static and
that new concerns about substances may arise as a result of new information becoming available.

d) Changes in the use of ZZS due to developments in society: as a result of the rapid development of innovations (but also due to changing requirements imposed by society), there are shifts in the demand for and supply of substances and raw materials, including ZZS. For example, the energy transition and a highly digitising society demand more specific substances for these applications, including ZZS. This is accompanied by the potential for new and different exposures to these substances, which in turn could lead to new risks. More information on this is provided in the practical example on lithium-ion batteries (Box 7).

**Box 7: Practical example: lithium-ion batteries**

Due to the rapid development in innovations, but also in response to changing demands in society, there are shifts in the demand for and supply of raw materials. For example, electric mobility as part of the energy transition is a result of new innovations and changing societal demands. Energy for electronics and electric cars is usually stored in lithium-ion batteries. The demand for this type of battery is expected to increase dramatically in the coming years, mainly driven by the automotive industry [Bosch, Exter et al., 2019; Martin, Rentsch et al., 2017]. In addition, existing batteries must be re-used or recycled to a greater extent to meet the growing demand for raw materials such as lithium, nickel and cobalt and to reduce geopolitical dependence. [Bosch, Exter et al., 2019; Zeng & Li, 2013].

Lithium-ion batteries may contain several ZZS, such as cobalt, acetonitrile, propane sulton, 1,2-dimethoxyethane or lithium-nickel dioxide [Hofstra, 2018; Kuppevelt & Klingenberg, 2019]. Exposure to these or other hazardous substances potentially not only occurs during battery production, but could also occur during accidents, vehicle collisions and during recycling. This is accompanied by potential risks for consumers and workers (in recycling and emergency assistance). Little is known about the exact risks involved.

Since lithium-ion batteries are being developed rapidly, we do not yet have an effective and scaled-up system in operation for recycling these types of batteries. Although car manufacturers are responsible for taking back their batteries, in practice the batteries are too complex in design for financially viable, high-quality recovery of raw materials. However, the batteries are re-used elsewhere for energy storage, such as solar energy (re-use/repurpose) [ARN, 2019; NRC, 2017; Wastenet, 2019]. The current design of lithium-ion batteries offers significant room for improvement to enable safe use and re-use, as well as providing stakeholders with accurate information.

**The necessity of integral assessment**

In order to make decisions about responsible handling of ZZS and the switch to a circular economy, it is necessary to make an integral assessment that includes not only the potential risks of the ZZS
substance but also other effects on society and the environment. An integral perspective is key in being able to reach a good decision that balances different values that our society considers important. Examples include: safety of substances, efficient use of materials and other aspects of reducing our environmental burden. Integral assessment may have different results for the (unintended) use of ZZS in applications of recycled material flows, compared to ZZS in new materials and products; such assessment must therefore be performed specifically for that in the context of recycling.

In 2018, the European Commission analysed the intersection points between laws and regulations on chemicals, products and waste, and invited interested parties (including individuals, companies, organisations and public authorities) to share their thoughts [European Commission, 2019]. This analysis included several elements that are also mentioned in this report. In a detailed response, the Dutch Government presents its perspective on the problems described by the European Commission. This vision outlines how the Netherlands deals with questions about recycling materials and products containing substances of concern. The Netherlands also calls on the Commission to come up with a generic framework for assessing the costs and benefits to society of using recycled materials containing hazardous substances [Rijksoverheid, 2019d].

Various methodologies for integral assessment of products are available, including sustainability assessment [Fernandez-Dacosta, Wassenaar et al., 2019; Zijp, Waaijers-van der Loop et al., 2017]. Examples of these integral (qualitative) assessment methodologies include LCA, Global Reporting Initiative, Dow Jones Sustainability Index and Sustainable Development Goals Compass [RIVM, 2019e]. However, these methods are not always capable of considering the risks of ZZS (and other substances of concern) and are generally not designed specifically for a circular system. RIVM recently proposed a number of methods for making an integral assessment of the desirability of recycling materials with ZZS. These are summarised briefly below:

- **Risk assessment framework for ZZS in waste** [Rijkswaterstaat, 2018; Zweers, Verhoeven et al., 2018]. This framework was developed as the basis for the risk analysis for recycled materials containing ZZS, as prescribed in the current National Waste Management Plan (LAP3). On the basis of four characteristics, it is decided whether or not it would be safe for waste containing ZZS to be used in a new application. This study examines the treatment options for waste flows, ZZS limit values, types of use, and the possibility of continuing to monitor the ZZS in the chain. This approach does not assess other risks, nor does it draw comparisons with the current situation. Furthermore, the outcome of the assessment depends on how the limit values have been derived/determined.

- **Safe and Sustainable Material Loops** [Quik, Lijzen et al., 2019]. This is a modular framework that provides a side-by-side comparison of the advantages and disadvantages of admitting materials/raw materials with ZZS. The ZZS module is based on [Zweers, Verhoeven et al., 2018]. In addition, there are modules for other risks such as pathogens and drug residues, but also for
effects such as contribution to the circular economy and environmental sustainability (energy and land use).

- **Clean material recycling project [De Blaeij, Bakker et al., 2019].** This is a framework (commissioned by the European Commission) intended for national authorities to support assessment within REACH restrictions, specifically for recycling. The framework offers a structure for assessing whether it is desirable for society to continue to permit use of secondary material with ZZS, and on what terms. A wide range of effects can be taken into account in this context.

We close this chapter with a final practical example about lead in PVC (Box 8). In this example, an explicit choice was made in considering whether to recycling existing material with ZZS, or to incinerate it.

**Box 8: Practical example: lead in PVC**

During production of rigid PVC, stabilisers are added to make it possible to process the material at high temperatures. Various lead compounds can be used. These lead connections are ZZS. A proposal to ban lead stabilisers in PVC was submitted recently [ECHA, 2017]. The question was whether recycling of rigid PVC containing lead should remain possible. The impact analysis showed that lead from PVC poses particular risks when the PVC is incinerated (flue gas cleaning does not capture 100% of the lead). Incineration causes airborne lead emissions, leading to human exposure via the environment. During normal use of rigid PVC and re-use after recycling, such emissions and exposure are not expected, or hardly at all. This means that recycling lead-contaminated PVC prevents risks, while simultaneously achieving material efficiency. However, it should be noted that lead emissions may still occur at a later stage (if the recycled PVC is later incinerated as waste). In order to avoid this, requirements must be set for monitoring these products in the chain, with additional efforts being made for chain partners (particularly in the case of re-collection and recycling). If the lead-contaminated material flow continues to exist, it is possible to eventually arrange for responsible disposal, if recycling is no longer possible or desirable at some point. Emissions of lead and other harmful substances will be prevented as much as possible.
4 Monitoring

4.1 Introduction

This chapter provides an overview of indicators and sources of information as possible components of a monitoring strategy for ZZS in a circular economy. A monitoring framework serves several purposes:

- It compares the extent to which the existing situation corresponds to the set objectives (accountability, communication and strategy adjustment);
- It explores the effects of possible measures (contributing to improved design of measures and decision-making);
- It evaluates the effect of measures already implemented (adjustment of previous measures);
- It monitors the situation to prevent or minimise unintended side effects.

RIVM proposes to distinguish between process monitoring and effect monitoring for ZZS in the transition to a circular economy, in accordance with the model presented by PBL/CBS/RIVM [PBL, 2019]. Process monitoring gradually provides information about resources (approach), activities (implementation) and performance (policy results). Effect monitoring measures the effects of these actions in relation to the policy objectives and possible trade-offs. Figure 3 shows an overview.

![Figure 3. Policy evaluation framework for monitoring progress of transition to circular economy, adaptation by RIVM (PBL, 2019).](image-url)
4.2 Indicators

The previously published report on monitoring the transition to a circular economy [Potting, Hanemaaijer et al., 2017] did not propose any indicators for safety and only mentioned the subject as a point for attention. In recent years, however, various reports have been published on indicators for monitoring ZZS at a national level [Gezondheidsraad, 2018; Leeuwen, Smit et al., 2014; Poorter & Leeuwen, 2016] and there are various tools that include ZZS (or substances of concern in a broader sense) for integral assessments at product level [RIVM, 2019e].

Whether an indicator is suitable for monitoring ZZS in the transition to a circular economy depends on the context in which it will be used as well as the policy objectives for which the monitoring results will be used. Table 2 provides an initial overview of possible indicators for ZZS monitoring in a circular economy. Some of the indicators could be operational in the short term, since they are based on currently available information. Other indicators call for the active collection of additional information that is currently not collected anywhere (or only partially). The indicators are grouped based on process monitoring and effect monitoring, but also according to the phase in the product chain. Indicators which can (partially) be traced back to information sources that are available right now, or within the short term, are underlined and numbered (#) in the table. Possible sources of information are indicated in Table 3.

Table 2 should be seen as an initial broad inventory of possible indicators for monitoring ZZS in the transition to a circular economy. It is therefore not a proposal for concrete implementation of ZZS monitoring.

In order to determine which of these indicators are most appropriate for the national monitoring and regional implementation programmes, it is necessary to use this report to work with stakeholders to determine the purpose of the monitoring and the context in which it will be used. Chapter 5 of this report presents recommendations for possible actions in the short and longer term to implement ZZS monitoring in the transition to a circular economy.
Table 2. Overview of potential indicators for monitoring ZZS in (the transition to) a circular economy, including an indication of the current information availability. (possible sources of the underlined and numbered (#) indicators are listed in Table 4).

<table>
<thead>
<tr>
<th>Phase in the chain</th>
<th>Monitoring of processes</th>
<th>Monitoring of effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resources</td>
<td>Activities</td>
<td>Performance</td>
</tr>
<tr>
<td>Public funds</td>
<td>Development of independent Safe &amp; Circular by Design programmes, education and criteria</td>
<td></td>
</tr>
<tr>
<td>available to</td>
<td>Safe &amp; Circular by Design objectives in corporate annual plans</td>
<td></td>
</tr>
<tr>
<td>promote/facilitate</td>
<td></td>
<td>Percentage of new products containing ZZS (1)</td>
</tr>
<tr>
<td>Safe &amp; Circular by</td>
<td></td>
<td>ZZS (number and volumes) present in new products (2)</td>
</tr>
<tr>
<td>Design</td>
<td></td>
<td>ZZS (number and volumes) present in imported products (3)</td>
</tr>
<tr>
<td>Private-sector</td>
<td>ZZS emissions during production phase (4)</td>
<td>Mapping ZZS dynamics: mass flows and portfolio changes (how quickly are old ZZS replaced by alternatives)</td>
</tr>
<tr>
<td>investments in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safe &amp; Circular by</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awareness of Safe</td>
<td>Initiatives to inform consumers about the presence or absence of ZZS in new or recycled materials and products (5)</td>
<td>Societal support for the use of secondary materials</td>
</tr>
<tr>
<td>&amp; Circular by</td>
<td></td>
<td>Emission of ZZS during the use phase due to consumption or wear and tear</td>
</tr>
<tr>
<td>Design during</td>
<td>Number of new innovations to reduce ZZS exposure during use phase</td>
<td></td>
</tr>
<tr>
<td>procurement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awareness during</td>
<td></td>
<td></td>
</tr>
<tr>
<td>procurement to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ensure safe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>recycling and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>re-use after use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Re-use, recycling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and waste</td>
<td>Number of recycling methods used that have a focus on ZZS removal</td>
<td>ZZS present in recycled (or otherwise re-used) products (number and volumes) (6)</td>
</tr>
<tr>
<td>Available means to</td>
<td>Number of recycling methods used that safeguard the responsible retention of ZZS in the material flow</td>
<td>Percentage of recycled (or otherwise re-used) products containing ZZS compared to recycled products not containing ZZS (7)</td>
</tr>
<tr>
<td>incentivise</td>
<td></td>
<td>Emissions of ZZS during (initial and subsequent) recycling phases (8)</td>
</tr>
<tr>
<td>recycling methods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>that remove ZZS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legal obligations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>for reduction of</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZZS Substances in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>recycled material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase in the chain</td>
<td>Monitoring of processes</td>
<td>Monitoring of effects</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Resources</td>
<td>Activities</td>
<td>Effects</td>
</tr>
<tr>
<td>Entire chain</td>
<td>Application of risk analysis based on LAP3 chapter B14</td>
<td>ZZS removed during recycling (number and volumes)</td>
</tr>
<tr>
<td></td>
<td>Number of initiatives to maintain information on materials and substances throughout the chain (e.g. material passports), with a focus on both circularity and safety of substances</td>
<td>Number of material passports containing ZZS information currently in circulation</td>
</tr>
<tr>
<td></td>
<td>Contracts with suppliers with a guarantee for safe use and re-use</td>
<td>Number of tenders in which the presence of ZZS in the entire chain has been taken into account</td>
</tr>
<tr>
<td></td>
<td>Emissions of ZZS during entire material flow (different planned material cycles)</td>
<td>Emissions of ZZS during entire material flow (different planned material cycles)</td>
</tr>
</tbody>
</table>

**Entire chain**

- Resources available to achieve chain monitoring for ZZS
- Number of initiatives to maintain information on materials and substances throughout the chain (e.g. material passports), with a focus on both circularity and safety of substances
- Contracts with suppliers with a guarantee for safe use and re-use
- Emissions of ZZS during entire material flow (different planned material cycles)

**Performance**

**Effects**

**Entire chain**

- Modelled exposure to ZZS
- Biomonitoring of ZZS [https://www.hbm4eu.eu/](https://www.hbm4eu.eu/)
- Number of accidents or burden of disease related to ZZS
- Potential biodiversity loss due to ZZS emissions (9)
- Potential life years lost due to exposure to ZZS
- Measured change in concentration of ZZS in indoor air, outdoor air, soil and water (10)
- Change in the amount of ZZS present in the technosphere and biosphere (air, water, soil, materials)
4.3 Available sources

European legislation (REACH/CLP and European waste legislation) sets requirements for the provision of information in the chain. This information can also be used for monitoring purposes. Table 3 shows the main potential sources of information for monitoring ZZS. In addition to the sources that are or will be available from the European regulatory framework, the table has been supplemented by other (national and international) initiatives that could serve as a source of information for the indicators listed in Table 2. The list provides a brief description for each source of information and discusses whether it can be used to monitor ZZS in a circular economy.

Table 3. Possible sources of information for indicators concerning ZZS in a circular economy.

<table>
<thead>
<tr>
<th>Available source</th>
<th>Description</th>
<th>Relation to indicator as shown in Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>REACH Regulation [ECHA, 2019c]</td>
<td>Information on SVHC substances in products available to consumers. This database contains information about the presence of substances on the ZZS list that are also SVHC* in products (*approx. 10% of the ZZS list). The contents of the database are based on the notifications (import articles) and registration files. It only links substance names to generic products, so it does not provide concentrations in specific products or total volumes. However, the number of notifications can offer an indication of how frequently a SVHC is used in products.</td>
<td>2, 3</td>
</tr>
<tr>
<td>SCIP Database [ECHA, 2019f]</td>
<td>Information about SVHC substances (&gt;0.1%) in products that can be accessed throughout the entire product chain (production, use, re-use/waste). Since all SVHC substances are included on the ZZS list, this database contains direct information about the presence of ZZS, although it does not provide a comprehensive overview. The database contains information about SVHCs present in specific products. The database is still empty at this point and should be operational in 2021.</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>Waarzitwatin.nl [RIVM &amp; VeiligheidNL, 2019]</td>
<td>Information on substances (i.e. a wider range than SVHC or ZZS) in generic product groups. Does not contain information on exact concentrations or specific products. Special attention is paid to safe product use.</td>
<td>2, 3, 5</td>
</tr>
<tr>
<td>Available source</td>
<td>Description</td>
<td>Relation to indicator as shown in Table 2</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Substances in Preparations in Nordic Countries [SPIN2000, 2019]</td>
<td>Information on the use of substances (quantities) including ZZS, in and for Norway, Sweden, Denmark and Finland. Data is linked to industries and generic applications, but not to (specific) products. The number of notifications can give an indication of how often a ZZS substance is applied. Not directly applicable for the Dutch market, but could help in prioritisation.</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>National Waste Management Plan 3 [Rijkswaterstaat, 2019b]</td>
<td>LAP3 calls for a risk analysis to determine whether the presence of ZZS in waste flows leads to unacceptable risks for humans and the environment. On this basis, it is decided whether or not to allow the recovery and re-use of these waste flows. This analysis contains information on ZZS in waste flows, but is carried out on a case-by-case basis. The results are not stored in a central database, which makes it difficult to access this information.</td>
<td>6, 7</td>
</tr>
<tr>
<td>Material passports</td>
<td>‘Material passports’ is a collective name used for datasets containing material information that travel (digitally) with products, for the purpose of use and/or re-use. There are several initiatives regarding such passports. These initiatives are currently often limited to one or several sectors (e.g. construction), certain steps in the product chain (e.g. information provided to consumers) or certain data (e.g. only generic material information). Information included in a passport is currently not centrally coordinated, so there are differences between the initiatives. For example, information on compositions, the presence of ZZS or other toxicity criteria is not always included.</td>
<td>1, 2, 3, 5, 6, 7</td>
</tr>
<tr>
<td>Available source</td>
<td>Description</td>
<td>Relation to indicator as shown in Table 2</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>Environmental annual report in digital format [Rijksoverheid, 2019a]</td>
<td>A Dutch application in which companies draw up and report their (industrial) emissions. The data are used in European reports. This database contains detailed data on the emissions of a limited set of ZZS (comprising several dozen). It provides information about the measures that companies have taken to minimise ZZS emissions, but not about the presence of ZZS in products. This information is in principle suitable for monitoring ZZS emissions, but the information it currently provides covers too limited a set of substances to be able to monitor the ZZS as a group. Embedding of ZZS policy in permits and licenses will most likely cause an increase in the information on ZZS in this database, eventually resulting in a more complete overview.</td>
<td>4, 8</td>
</tr>
<tr>
<td>The Netherlands Pollutant Release and Transfer Register [Rijksoverheid, 2019b]</td>
<td>A central database containing records on emissions into soil, water and air, tracking around 350 substances and substance groups relevant to environmental policy. It contains the data from individually registered point sources (based on e.g. environmental annual reports from companies) and diffuse sources (emissions calculated by expert groups), including the locations where these emissions occur. The database contains detailed data on the emissions of a limited set of ZZS (a few dozen in all). This information is in principle suitable for monitoring ZZS emissions, but the information it currently provides covers too limited a set of substances to be able to monitor the ZZS as a group.</td>
<td>4, 8</td>
</tr>
<tr>
<td>European Pollutant Release and Transfer Register [InfoMil, 2019b]</td>
<td>European annual environmental report by industrial companies, in which they report on their waste management, energy and water use, and emissions to air, water and soil. For the Netherlands, the data in this emissions register are the same as those in the ePRTR.</td>
<td>4, 8</td>
</tr>
</tbody>
</table>
Available source | Description | Relation to indicator as shown in Table 2
---|---|---
National Air Quality Monitoring Network (LML) [Ministerie van Infrastructuur en Milieu, RIVM et al., 2019] | This network measures the substances present in the air as gases or suspended particulates. It also measures substances that are being precipitated in rainwater. Two ZZS (carbon monoxide and benzene) are measured in the LML. These measurements are in principle suitable for monitoring environmental concentrations of ZZS, but currently provide information on too limited a set of substances to be able to monitor the ZZS as a group. | 10
Provincial air quality systems | Several provinces have an air quality measurement network, such as the Air Measuring Network of the Rijnmond Environmental Protection Agency (DCMR) [DCMR Milieudienst Rijnmond, 2019]. These measuring networks do not measure any ZZS, or only a few. These measurements are in principle suitable for monitoring environmental concentrations of ZZS (to the extent that they are measured), but provide information about too limited a set of substances to be able to monitor the ZZS as a group. | 10
Water quality measurements by Rijkswaterstaat [Rijkswaterstaat, 2019c] | The Directorate-General for Public Works and Water Management (Rijkswaterstaat – RWS) conducts a large number of water quality measurements, determining both biological and chemical water quality. Various ZZS are also measured in the context of chemical water quality. These measurements are suitable for monitoring environmental concentrations. | 9, 10
ZZS emissions database | This is part of Dutch policy on ZZS emissions. As a result, companies that have a mandatory license are legally obliged to report the actual ZZS emissions to the competent authority at least once every five years, together with a report on what the company will do to further minimise emissions. On behalf of the Ministry of Infrastructure and Water Management, RIVM has created a database for the safe storage and retrieval of emission data on ZZS. Agreements on filling the database and reporting on that basis will be made in 2020. | 4, 8
The overviews in Tables 2 and 3 provide an initial step for indicators and sources of information that can be used for monitoring ZZS in (the transition to) a circular economy. Most of the information available from these sources on monitoring is primarily related to the production phase. The flow of information through the (often complex) chain is currently usually limited. Moreover, the available sources are often focused on part of the ZZS list (such as SVHC) and limit values are often used, which means that some information does not become available at all.

On the basis of this inventory of indicators and associated sources, it appears that it will be impossible to outline a comprehensive picture of ZZS in a circular economy in the short term. For many indicators, there are simply no sources of information available – or not yet – and the sources of information that are available do not provide a comprehensive overview of all ZZS throughout the chain.

However, initial steps can be taken to set up ZZS monitoring in a circular economy. This requires supplementation and final selection of indicators and sources for the national monitor and the individual transition agendas. This goes hand in hand with prioritisation steps for relevant indicators that we can measure in the short term, as well as indicators that we cannot yet measure, but do want to measure in order to provide full coverage. More information is required here.

Chapter 5 provides more detail on the initial steps to be taken for monitoring within the context of the transition dynamics and presents recommendations for monitoring actions in different time periods. For the concrete implementation of ZZS monitoring in the transition to a circular economy, it will be necessary to align with the broader CE monitoring activities and the Working Programme on Monitoring and Managing CE 2019-2023. One of the important aspects here is linking with the Raw Materials Information System (Grondstoffen Informatie Systeem – GRIS) which is being set up.
5 Recommendations

This chapter aims to:
- provide a number of concrete recommendations in taking steps to address the challenges described in Chapter 3;
- proceed from the monitoring possibilities identified in Chapter 4 to actually launching monitoring activities.

What actions do we envision as a first logical step towards the responsible use of ZZS in the transition to a circular economy? And to be able to monitor ZZS in this transition? As in Chapter 3, we distinguish between the following three challenges:
1. Availability of information on ZZS in the supply chain;
2. Expand responsibility throughout the entire product chain;
3. Safe handling of ZZS in a circular economy where phasing out is impossible, or is no longer possible.

5.1 Long-term outlook

The transition to a circular economy and how to cope with ZZS in that context requires a long-term vision that can be used to determine concrete actions for the short, medium and long term. Over time, the actions can be adjusted as needed.

This chapter is based on the following vision of the future for 2050: Defined raw materials are infinitely and safely circulated in technical or biological cycles. In this scenario, ZZS will only be accepted in essential uses and as long as there is no unacceptable risk to human health and the environment, taking into account side-effects or shift-offs.

The future scenario described above is an example of a possible long-term option that will be helpful in determining concrete actions. It is important to realise that this is not the only possible long-term option, and that it is not free from value judgements. Where the dot is placed is in fact a political choice. The choice of this picture of the future is not intended as a prediction or reflection of policy, although existing policy initiatives on CE and a non-toxic environment have been taken into account. A crucial factor in this picture of the future is how ‘essential’ uses are defined and how the use of ZZS is balanced against other aspects such as climate change, energy consumption and safety. Establishing a long-term vision or common goal is one of the recommended actions needed for responsible handling of ZZS in a circular economy. This report offers an initial attempt.

The following recommendations for actions for both policy development and monitoring can be seen as a starting point for a more widely discussed and supported agenda for research, monitoring and policy. The recommendations and actions should be periodically evaluated and adjusted as needed.

In the following sections, we propose various action lines for each recommendation in order to achieve the 2050 vision. These action lines are divided into three time blocks:
• Short term (2020-2021);
• Medium term (2021-2030); and
• Long term (2030-2050).

Each action line is developed per time block. In the short term, this usually involves prioritising and taking inventory. The continued concretisation of policy objectives regarding ZZS and CE, and efforts to combine those policy objectives, becomes increasingly relevant as time progresses and we draw closer to the vision of the future that we are working towards. In the short term, even on the basis of an overall picture of the final goal, meaningful actions can be mapped out, which are less dependent on how the goals are concretised from there. These are the short-term actions that would be advisable to implement now, regardless of any other considerations. The proposed short-term actions mainly tried to include these ‘no-regret actions’.

The transition to a circular economy takes place in a complex and dynamic playing field with new technologies and substances, shifting requirements for raw materials, and other substances and new policy intentions. Deviating policy goals, new insights developed over time, and continued discussions with stakeholders may lead to different actions with regard to ZZS. Their aim is also to continue the discussion on this research, monitoring and policy agenda and, on that basis, to address and implement initial actions, in consultation with various parties. It should also be specified which parties are at the forefront of which actions. This has not yet been explicitly stated in the current elaboration of the proposed actions.

5.2 Availability of information

In order to be able to re-use raw materials safely and frequently, information about compositions and applications must be available throughout the entire chain. To achieve this, we propose three action lines: criteria for information, information systems and monitoring (see Table 4). These action lines are worked out into actions per time block. These actions involve providing access to information about ZZS in the chain. What will be done with this information, and how this information will be used for responsible handling of ZZS, are next steps that will be addressed in part in the other challenges.

3 In Tables 4, 5 and 6, a number of short-term actions are shown in blue. These actions are presented as priorities and are explained after the tables.
**Table 4. Information in the chain, action lines with actions per time block.**

<table>
<thead>
<tr>
<th>Action line</th>
<th>Actions 2020-2021</th>
<th>Actions 2021-2030</th>
<th>Actions 2030-2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria for</td>
<td>Draw up criteria for necessary data (availability and quality) for materials</td>
<td>For all new products (including imports), information is available in accordance</td>
<td>For all new and existing products (including imported), information is available</td>
</tr>
<tr>
<td>information</td>
<td>and substances (including ZZS) throughout the chain</td>
<td>with the selected criteria, first for SVHC (2025) and then for ZZS (2030)</td>
<td>in accordance with the chosen criteria for complete compositions (including a wide</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>range of substances of concern)</td>
</tr>
<tr>
<td>Information</td>
<td>Draw up an inventory of available information systems and selection of most</td>
<td>Evaluate system and adapt according to information criteria. Where possible, connect</td>
<td></td>
</tr>
<tr>
<td>system</td>
<td>appropriate options, OR set up new system for the selected criteria</td>
<td>to the SCIP database and the GRIS</td>
<td></td>
</tr>
<tr>
<td>Monitoring</td>
<td>Number of initiatives to retain information on materials and substances through</td>
<td>Number of completed datasets or passports per initiative. Particular attention will</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the chain, with a focus on circularity and on safety of substances</td>
<td>be paid to the completion of the SCIP database and the GRIS. This provides insight into the availability of information for all parties in the chain</td>
<td></td>
</tr>
</tbody>
</table>

**Criteria for information | 2020-2021**

In 2020-2021, unambiguous criteria will be drawn up (or adopted) for the required data. These criteria will determine what information must be available (as a minimum) and what the (minimum) quality of the data must be in order to achieve safe re-use. It concerns information about materials and substances (including ZZS). In order to facilitate safe handling of substances, this information must be transparent throughout the chain or through multiple chains. Since applications in a circular economy can change and create new risks, end-of-use scenarios should be part of this information flow. The criteria can be harmonised with the FAIR principles [GO FAIR, 2019]. In addition, it is important to be able to offer an indication of the reliability of the available data. It is key to take into account the needs of stakeholders in the chain when drawing up criteria.

We propose working out the implementation of this action (line) in a step-by-step plan, focusing on availability of minimal information at first and then on providing more extensive information throughout the chain. For example, it is possible to start compiling information about the presence of SVHCs above a certain concentration limit, in order to eventually work towards complete information about compositions and end-of-use scenarios.
**Information system | 2020-2021**
This action line is about setting up or identifying a system or systems for providing information in the chain. A good system offers the option to align with the development of information criteria, protects confidential information where necessary (e.g. to protect competitively relevant data), facilitates information exchange with parties and other systems, and can be used internationally. The system will be periodically evaluated and adjusted where necessary. A potentially suitable system is the ECHA (EU) SCIP database and the GRIS (NL) database, both of which are under development [ECHA, 2019f; PBL, 2019].

**Monitoring | 2020-2021**
In order to monitor the status and progress in the provision of information, it is relevant to take stock in the short term of initiatives that already exist for the retention of information on materials and substances (including ZZS) throughout the chain (process monitoring). The focus is on both circularity and safety and on the extent to which the initiatives are used (number of passports or datasets per initiative).

*More specifically, we recommend monitoring the development of the SCIP database and its implementation. Information retention systems in the chain can, as they are applied more widely, also serve as a source of information for monitoring in the future.*

### 5.3 Expanding responsibility
Prevention of ZZS risks can be achieved by introducing more extensive responsibility for stakeholders in the product chain. When using ZZS, producers take into account how the product can be safely used and re-used, and communicate about that. It is based on the principle that companies should only be allowed to continue operating if they take responsibility for the entire product chain and the possible use of ZZS in that chain. The government can contribute to this through measures that promote expanded producer responsibility, but also by setting a good example and defining a procurement policy that involves purchasing products designed in accordance with Safe & Circular by Design criteria and limiting the use of ZZS wherever possible.

*In order to bring about this expanded chain responsibility, we propose implementing the action lines described in Table 5.*
Table 5. Extensive chain responsibility, action lines with actions per time block.

<table>
<thead>
<tr>
<th>Action line</th>
<th>Actions 2020-2021</th>
<th>Actions 2021-2030</th>
<th>Actions 2030-2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prioritisation</td>
<td>Prioritise materials, product groups, sectors and ZZS</td>
<td>Periodically evaluate priority flows and expand scope</td>
<td>Require that &gt;x% of all new products within priority flows meet Safe &amp; Circular by Design criteria and have been produced without ZZS (ZZS-free) (with an exception for essential uses)</td>
</tr>
<tr>
<td>Criteria for Safe &amp; Circular by Design</td>
<td>Identify and draw up criteria for Safe &amp; Circular by Design for priority flows, paying explicit attention to the use of ZZS in that context</td>
<td>Require that &gt;x% of all new products within priority flows meet Safe &amp; Circular by Design criteria and have been produced without ZZS (ZZS-free) (with an exception for essential uses)</td>
<td>Require that &gt;y% of all new products within priority flows meet Safe &amp; Circular by Design criteria and have been produced without ZZS (ZZS-free) (with an exception for essential uses)</td>
</tr>
<tr>
<td>End-of-use scenarios</td>
<td>Draw up criteria and create templates for end-of-use scenarios and business plans for new products</td>
<td>For all new products within priority flows containing ZZS (including recycled products): require the presence of an end-of-use scenario</td>
<td>For all new and existing products within priority flows: require the presence of an end-of-use scenario that takes ZZS into account</td>
</tr>
<tr>
<td>Education and public information</td>
<td>Set up an education and information programme for various stakeholders within priority flows, which incorporates Safe &amp; Circular by Design as well as end-of-use scenarios and ZZS</td>
<td>Implement and adapt an education and information programme for new priority flows</td>
<td></td>
</tr>
<tr>
<td>Procurement policy of the Dutch government</td>
<td>Draw up criteria for ZZS for procurement policy, aligning them wherever possible with criteria for Safe &amp; Circular by Design</td>
<td>Apply procurement and tendering criteria and periodically evaluate and refine them.</td>
<td></td>
</tr>
<tr>
<td>Monitoring</td>
<td>Monitor the application of Safe &amp; Circular by Design by manufacturers and monitor the use of ZZS in products and services purchased by the government</td>
<td>Monitor the presence of ZZS in new products, using existing systems as much as possible to reduce the administrative burden.</td>
<td>Monitor exposure of workers, users, and the environment to ZZS, using existing systems as far as possible to reduce the administrative burden</td>
</tr>
</tbody>
</table>

**Prioritisation | 2020-2021**

It is recommended to prioritise materials, product groups or sectors in relation to ZZS, applying the expanded product responsibility to those substances first. It is important to take into account a level playing field, limited administrative burdens and a fair distribution of administrative and other burdens. It may also be necessary to determine which ZZS are given priority.

From a practical point of view, it is not realistic to start with all products and materials, let alone all ZZS. Prioritisation makes the actions more manageable in scope, and they can later be applied to other materials, product groups and sectors as well as to other ZZS. In addition, prioritisation gives focus to the monitoring strategy, in determining what can be monitored in the short term and what else is needed to obtain a
comprehensive picture. The following aspects can be taken into account in the prioritisation process:

- Scope of the material flow, product group or sector;
- Presence of ZZS in the material flow [Wassenaar, Janssen et al., 2017], product group or sector (numbers and volumes);
- Degree of ZZS exposure of workers, users and the environment for the material flow, product group or sector;
- Representation of all transition agendas in the selected material flows, product groups or sectors;
- Most common ZZS in a selected material flow, product group or sector;
- Availability of usable data for indicators.

**Criteria for Safe & Circular by Design and end-of-use scenarios | 2020-2021**

For Safe & Circular by Design and end-of-use scenarios for the priority flows described above, case studies and stakeholder needs from the chain criteria can be drawn up using existing guidelines and tools. It is important that the focus here is explicitly on substances of concern and ZZS. Within the end-of-use scenarios, it may also be necessary to draw up 'waste criteria': the point at which cycling a product or material is no longer possible, and the best course of action is to incinerate the product with energy recovery, or transform it into building blocks via chemical recycling (R8, R9).

**Monitoring | 2020-2021**

In the short term, it is possible to start monitoring producers who already apply Safe & Circular by Design criteria in production processes for the selected priority flows (to the extent that they are currently available). In the medium term, this can be expanded by monitoring ZZS (number of ZZS, volumes, percentage of products with ZZS) in new products.

In addition, it would be possible within the short term to identify government procurement processes in which ZZS play a (major) role. As far as those purchases are concerned, the government can influence the market by using its purchasing power to steer towards ZZS-free purchasing. In the medium term, it will be worthwhile to track realisation of the effect of purchasing ZZS-free innovations and to evaluate the results and make adjustments as needed.

**5.4 Safe handling of ZZS**

Even in a circular economy, ZZS will continue to be used. ZZS are found in many products and materials that exist today, and it will be difficult or impossible to phase them all out (see 3.4). Additional policy measures that include operational perspectives will be needed to handle ZZS responsibly in a circular economy. During the transition, decisions need to be made regarding whether or not to re-use raw materials and the ZZS they contain. However, other factors (such as side-effects and shift-offs) also play a role in making choices about ZZS and CE and may influence these considerations. To ensure responsible handling of ZZS, it is important for these integral assessments to be based on complete, accurate information.
In order to bring this about, we propose implementing the action lines in the timeline (Table 6). The most important short-term actions are again highlighted after the timeline.

Table 6. Safe handling of ZZS, action lines with actions per time block.

<table>
<thead>
<tr>
<th>Action line</th>
<th>Actions 2020-2021</th>
<th>Actions 2021-2030</th>
<th>Actions 2030-2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concretisation and definition of ZZS policy in a circular economy</td>
<td>Fine-tuning and harmonising targets for ZZS in CE and defining prerequisites</td>
<td>For example: in addition to the current policy where ZZS are only allowed to be applied or re-used if there are no unacceptable risks, prohibit ZZS in or for decorative uses</td>
<td>For example: continue to extend the ban on ZZS use in or for decorative uses by only allowing the use (and re-use) of ZZS in essential uses</td>
</tr>
<tr>
<td>Prioritisation</td>
<td>Prioritise materials, product groups, sectors and ZZS</td>
<td>Periodically evaluate priority flows and priority ZZS and expand scope</td>
<td>Aligning laws and regulations to policy objectives</td>
</tr>
<tr>
<td>Integral assessment</td>
<td>Test and developing an assessment framework and sample library for integral decision-making on coping with ZZS in a circular economy</td>
<td>Periodically evaluate and refine the assessment framework in order to (continue to) align with transition dynamics and long-term policy goals. For example, coping with multiple ZZS in material flows requires attention with multiple ZZS in material flows.</td>
<td>Case-by-case approach via assessment framework for allowing ZZS in (recycled) materials, drawing generic lessons learned from case experiences</td>
</tr>
<tr>
<td>Curative measures</td>
<td>Explore possibilities to incentivise techniques for identifying, tracing, separating or removing ZZS in recycling flows where retaining ZZS in the system would be undesirable. Make a start according to the priorities chosen</td>
<td>Evaluate which further actions are needed to incentivise the development of techniques that promote responsible handling of ZZS in material flows</td>
<td>Setting up second-line advice (e.g. a helpdesk) for integral assessment, including safety</td>
</tr>
<tr>
<td>Monitoring</td>
<td>Monitor the use of integral assessment frameworks with a focus on ZZS</td>
<td>For priority flows, monitor for the presence of (legacy) ZZS</td>
<td>Monitor exposure of workers, users and the environment to ZZS</td>
</tr>
</tbody>
</table>
**Concretisation of policy objectives | 2020-2021**

This action includes fine-tuning and harmonising targets for ZZS in CE and defining the prerequisites. This mainly deals with the issue of how policy goals for ZZS can be combined with policy goals for the circular economy. If the final objectives are clear, actions for policy and industry can be managed more and more effectively. For ZZS in a circular economy, the ultimate goal may be that these substances are only applied in new/recycled materials in the context of essential use. Crucial actions in this context include:

- Definition of essential uses by sector/product group;
- Determine how the use of ZZS can be weighed against other possible risks to humans and the environment and against the socio-economic benefits of using ZZS (see integral assessment).

When the aforementioned objectives and prerequisites are clear, follow-up steps for the medium and long term can be designed and implemented.

**Prioritisation | 2020-2021**

In order to cope with ZZS safely, it is important to prioritise materials, product groups, sectors and ZZS, similar to prioritising how information is provided in the chain and how chain responsibility is achieved. See Section 5.3 (Prioritisation) for a more detailed explanation of this action.

**Integral assessment | 2020-2021**

In order to be able to learn from practice, it is important to test the use of integral assessment frameworks and to set up a sample library for integral decision-making. Based on the priorities selected, a number of cases can be evaluated for each sector/material flow/product flow/ZZS substance to determine whether or not allowing ZZS in these flows would be advisable for society. In this context, it is necessary to determine the pros and cons of various options for coping with ZZS in these material flows. Based on the outcomes, the assessment framework can be defined in more detail.

Subsequently, it is important to take stock which assessment frameworks (at various policy levels) should take the use of ZZS into account and to check whether this is already happening. Where integral assessment with a focus on ZZS is not yet taking place, this can be introduced. Based on the experiences, the assessment framework can be periodically evaluated and fine-tuned to ensure that it remains in line with the transition dynamics and steers towards the final objectives.

**Monitoring | 2020-2021**

In the short term, it is possible to set up monitoring for the use of integral assessment frameworks with a focus on ZZS. It is particularly important to identify where integral assessments with a focus on ZZS are already being used (e.g. by companies) and to gauge where there is potential to apply such assessments in the long term.

In this chapter, we have used the identified challenges to map out tangible first steps for safe handling of ZZS in a circular economy. We wanted to pay attention to the management of both the front-end (Safe & Circular by design, well-founded choices) and the back-end (improved
recycling). This is intended as a starting point for a more widely discussed and supported agenda on research, monitoring and policy.
Commissioned by the Netherlands Environmental Assessment Agency (PBL), RIVM explored the main points for attention in responsible handling of ZZS in a circular economy and provided suggestions for monitoring. This report identifies the main challenges for this theme: (1) availability of information in the chain on ZZS, (2) expanded responsibility throughout the product chain and (3) safe handling of ZZS in a circular economy where phasing out is not possible. Next, possible indicators and sources of information for monitoring ZZS in (the transition to) a circular economy were analysed. Finally, based on a vision for 2050, recommendations have been made for short-term, (2020-2021), medium-term (2021-2030) and long-term (2030-2050) actions to achieve this vision. These recommendations encompass the challenges as well as monitoring.

This report aims to contribute to the discussion on coping with ZZS in a circular economy. The transition to a circular economy and the role of ZZS in that context is taking place in a complex and dynamic playing field with new technologies and substances, shifting requirements for raw materials and other substances and new policy intentions. The suggestions and ideas in this report are intended as a starting point for continued discussion on the interpretation of a research, monitoring and policy agenda for ZZS in a circular economy.

We hope that this report will encourage readers to reflect more on these issues. In our experience, it is very easy in various forums to toss around such statements as: "We must ban all ZZS as soon as possible" or "ZZS must never end up in recycled material". Or, in other forums: "As long as there is no risk, there is nothing wrong and all uses should be allowed" or "100% product and material cycling results in win-win situations for everyone". In reality, the situation is far more complex. Information on the properties and application of substances is limited. Making chains safe and circular requires a great deal of effort on the part of everyone involved and does not take place overnight. Responsible handling of ZZS in a circular economy requires extensive analysis and discussion, as well as the right information and tools to make responsible choices. In addition, it is good to realise that although there are major challenges concerning ZZS in the transition to a circular economy, the transition to a circular economy also offers opportunities to tackle these challenges and to take a smarter approach to ZZS and avoid their potential risks.
Reflections by external parties

In this report, RIVM explores responsible handling of ZZS in the transition to a circular economy. In doing so, RIVM attempts to answer the main question of this report:

What are the main challenges for responsible handling of ZZS in (the transition to) a circular economy and what first steps can be taken to monitor ZZS in a circular economy?

The report should expressly be considered an exploratory study in which RIVM sheds light on this main question. The purpose of this report is to draw attention to ZZS in the transition to a circular economy and to support continued discussion with government authorities, businesses and community organisations. In order to examine not just this impression offered by RIVM, but also the ideas of other stakeholders, we asked a number of external experts to reflect briefly on the aforementioned main question and the present report. These reflections are provided below and outline an overview of the perspectives of a number of stakeholders from the field of ZZS and CE.

7.1 Reflection by Dr G. Roebben

Policy Officer REACH Unit, DG Grow, European Commission, in a personal capacity

For a long time, the concept of a circular economy (maximum re-use of goods and materials) was a dominant factor in human behaviour, since raw materials and new products were scarce and therefore expensive (compared to average purchasing power). The 'linear-economic' consumer society, which developed mainly after WW2 and brought wealth and purchasing power to a growing number of people, is a much more recent development, but the predicted growth limits of this model seem to have been reached.

A return to a more circular economy poses a challenge for society as a whole. However, a circular economy is not the end goal in itself. It is a means of achieving more fundamental objectives, in particular the protection of the environment and biodiversity from uncontrolled exploitation of primary raw materials and, as a matter of particular urgency, mitigation of the effects of climate change. It is therefore important to take the right steps first in the transition to a (more) circular economy. Maximum removal of ZZS from recycled materials is an obvious priority, not solely for direct health or environmental reasons, but also indirectly, based on the need for certainty regarding respect for legal standards in the substitution of primary raw materials with secondary raw materials.

The Letter Report provides a thorough overview of the issues relevant to the use of ZZS in a circular economy. The report emphasises the need for a balance between ambition and realism. In this context, there are still many open questions, including:

- Who has the knowledge and the means to weigh the pros and cons of certain ZZS in certain applications and to give well-
founded technical and scientific advice on allowing the use of these particular ZZS, taking into account general toxicity, ecotoxicity, and economic and climate considerations?

- Where should the discussion take place and the decision made on what specifies the essential use of a ZZS substance? And what is the significance of the social aspect (the ‘just transition’) and the geopolitical aspect?

7.2 Reflection by Dr J. de Bruijn

Director of Prioritisation and Integration, European Chemicals Agency (ECHA)

This RIVM report on Coping with Substances of Concern in a Circular Economy addresses an important issue at the intersection of policies on substances and on waste management: how can we ensure that we only use substances in the future that are produced and applied sustainably and can ultimately be fully re-used in material cycles without generating undesirable risks for humans and the environment? This is by no means an easy task; quite rightly, this report looks for potential actions in the short, medium and long term, realising that this objective requires a fundamental change in industry choices in production processes. The cross-border nature of many product flows and waste flows necessitates an approach at the EU level, and probably at the global level, as has also been explicitly recognised in the recently published European Green Deal4 of the new European Commission.

Significantly improved information on the application of hazardous substances in the use chain as expressed in Challenge 1 is indeed an absolute must. Prioritisation is key here, but given the dynamic nature of the ZZS list (and the European SVHC list) and the advancing scientific insights into how harmful substances are, it is a matter of urgency to obtain a complete product composition and to design future information systems and formulate related government policy on that basis from the outset. If we don’t do this, the ‘legacy spectre’ will continue to haunt the industry for decades to come. In addition, it paves the way for the marketing of ‘ZZS-free products’, a trend that the more progressive sectors are very likely to embrace with a view to achieving the UN 2030 Sustainable Development Goals.

This report rightly identifies increased chain liability and the presence of a suitable assessment framework as very important additional prerequisites. In my view, the need to give this assessment framework an integral character, covering not only safety aspects but also other environmental impacts of the production and use of substances, cannot be overemphasised. Achieving effective sustainable management of hazardous substances goes beyond avoiding exposure of humans and the environment to ZSS substances.

7.3 **Reflection by D. van Well**

Senior Advisor Chemical Policy and Occupational Health, Royal Association of the Dutch Chemical Industry (VNCl)

The chemical industry supports both the ambition to make the transition to a circular economy (CE) and the ambition to minimise or prevent exposure of humans and the environment to substances of concern. The challenges described in the report correspond to a large extent to the priorities (or more accurately: framework conditions) of the chemical industry:

- The necessity of applying integral life-cycle thinking / Safe by Design / cradle-to-cradle;
- Involving the entire chain in responsible handling of products;
- Safe handling of substances in the circular economy;
- Increased transparency without compromising confidential business information.

Successful realisation of a circular economy also requires, at the very least (*conditio sine qua non*), a harmonised approach within Europe. After all, flows of substances and materials move all over the world. In terms of substances policy, this means agreement on what exactly constitutes a substance of concern, clear long-term objectives and prerequisites/actions to achieve them. The R-strategies (or the comparable RESOLVE framework⁵) provide useful practical tools for operationalisation (which are now used by many chemical companies).

The report observes that the two aforementioned ambitions cannot be combined properly in all cases and in some cases even contradict each other. This analysis corresponds to that of the chemical industry. The dilemmas that arise in the use of substances of concern (and alternatives to those substances) call for **integral** assessment – not just of the toxicological risks of substances of concern and their alternatives, but also of how alternatives affect other risks, e.g. in terms of the use of raw materials and energy and (in the case of the use of bio-based materials) biodiversity and possible competition with food supply.

The chemical industry is fully committed⁶ to achieving circularity in products or, at the very least, to efficient recovery of products and energy. In addition, it can be stated with regard to the handling of 'legacy' products/materials, (ongoing) tests indicate that chemical recycling of plastic waste is a very promising line of research, as a technology to remove SVHCs from material cycles.

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⁵ [https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Sustainability/Our%20Insights/The%20circular%20economy%20Moving%20from%20theory%20to%20practice/The%20circular%20economy%20Moving%20from%20theory%20to%20practice.ashx](https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Sustainability/Our%20Insights/The%20circular%20economy%20Moving%20from%20theory%20to%20practice/The%20circular%20economy%20Moving%20from%20theory%20to%20practice.ashx)

7.4 Reflection by Dr J. C. Slootweg

Senior university lecturer on circular chemistry, Van ’t Hoff Institute for Molecular Sciences, University of Amsterdam

An important report that reflects the current state of affairs and rightly emphasises the focus on monitoring and safe & circular design. ZZS present problems in our current linear economy; an overview of these substances will provide the basis for the analysis on coping with ZZS in (the transition to) a circular economy in which raw materials and products are re-used/recycled. Monitoring is vitally important here. A circular economy can provide solutions, but may also lead to ZZS accumulation and increased risk of exposure to ZZS.

The crux is to prevent ZZS (and waste products) from ending up in the biosphere. The planetary boundaries concept of Rockstrom et al makes this clear. Ideally, the most ideal R-route / circular use should be designed and developed for each product or product group to ensure safety, even from the ZZS present. Figure 1 (R-strategies for re-using materials) provides an accurate overview of the available R-routes. In addition to this overview, I propose expanding the recycling loop to include recovering substances (ZZS, waste) or making them harmless. For molecules and materials to be recycled, they must first be recovered (preferably in pure form). Not all materials are suitable for recycling (e.g. complex mixture of compounds in wastewater), so the possibility of rendering them harmless in the biosphere should be added. In short, in addition to R8. recycling, I propose to add the following (in one form or another):

1) biodegraded in the environment and converted into harmless species,
2) degraded by human intervention and converted into harmless species (e.g. at wastewater treatment plants),
3) recovered (R9) from the biosphere to allow subsequent recycling (R8) by using waste as resource.

7.5 Reflection by Professor G.J.M. Gruter

Industrial Sustainable Chemistry, Faculty of Science, Van ’t Hoff Institute for Molecular Sciences, University of Amsterdam

I would like to answer the question regarding this issue for my own area of expertise, specifically synthetic materials (e.g. polymers, plastics) and the building blocks (monomers and intermediates) that are used to produce these plastics. This is a relevant field because 80% of all chemical raw materials (6% of crude oil) are used for the production of plastics (350 million tonnes per year worldwide and about 7 million tonnes per year in the Netherlands). The ZZS issue in the plastics field differs significantly from the scenarios primarily described in this RIVM Letter Report (see, for example, the scenarios in Section 3.1). The production of many conventional plastics involves the use of monomers and intermediates that are ZZS themselves, but end up in another non-ZZS form in the plastic (e.g. benzene or phenol as intermediates and monomers such as butadiene in rubber, acrylonitrile, butadiene and

7 https://science.sciencemag.org/content/347/6223/1259855
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styrene in ABS, and vinyl acetate in PVAC and EVA). In these cases, the polymerised ZZS substance no longer poses a risk (ABS can be used safely for e.g. toys such as LEGO); the issue here is the amount of monomer remaining in the plastic. Without cheap sustainable alternatives, there will be no large-scale ban on these plastics. A European ban on single-use plastics has a different driver than ZZS (according to the definition in Section 2.1): plastic soup.

Recycling plastics is a different challenge in terms of ZZS. When plastics are melted (mechanical recycling), this may lead to the formation of ZZS. These may not necessarily be the same ZZS as the substances used to make these plastics. ‘Safe & circular by design’ for new plastics is therefore not limited to choosing safe monomers, but also requires evaluation of ZZS formation during thermal decomposition. Incidentally, it is not the case that 50% recycling of plastics will lead to 50% less use of primary raw materials for these plastics. Only 2% of all packaging goes into closed-loop recycling (for the same application); this is only a fraction of the PET bottles used. For non-packaging, this percentage is even lower. Chemical recycling of polyolefins (PE, PP), via pyrolysis and cracking, produces many products but only a small proportion of ethylene and propylene. In other words, even at high recycling percentages, a large quantity of primary raw materials remains necessary to produce plastics. In terms of energy, there are many alternatives to fossil fuels, but in terms of producing plastics, the only sustainable alternatives are biomass and eventually CO₂.

In the transition to sustainable raw materials and a circular economy, it is certainly advisable to minimise (or eliminate) the use of ZZS building blocks wherever possible. This avoids possible problems with production, storage and transport and problems regarding residual ZZS monomers in the plastics. If we also start using considerably more condensation polymers (polyesters, polyamides, polycarbonates), then we can use chemical recycling to go back to the monomers (closed loop!). This will avoid the formation of unwanted ZZS that may be created during mechanical recycling or pyrolysis.

**7.6 Reflection by Professor T.H.M. Sijm**

*Faculty of Science and Engineering, Maastricht University*

I will start by reflecting on the first substances of concern identified in history. For instance, lead was used by the Romans in glassware and caused neurological problems. Almost two thousand years later, the PCBs that led to all kinds of undesirable health effects on polar bears in the food chain became notorious, as did the dioxins which led to nasty environmental impacts. The Romans had no laws regulating chemicals, but later it became epidemiologically clear that they should not use lead glassware. Less than 1% of PCBs were found to be leaking to the environment, but those leaks did lead to a global problem. Dioxins turned out to be a by-product of defoliant (Agent Orange) and to be formed during incineration processes. Those PCBs and dioxins are now banned worldwide.

In principle, the regulatory framework can now identify substances with properties like those mentioned above as possible substances of very
high concern. The important assumption here, which is also mentioned in the RIVM Letter Report, is that we are familiar with these substances and their properties, and that these substances are produced by people and marketed in known quantities. To that end, RIVM recommends 1) that this information be shared throughout the product chain, 2) that all parties in the product chain ensure that materials and products can be re-used safely and 3) that producers start considering these properties as early as the design stage. That is good advice, but do not forget that many substances are used in small quantities or low percentages, and that there are also Non-Intentionally Added Substances (NIAS) that can also be a source of great concern. Therefore, in addition to the RIVM recommendations mentioned above, my advice is to monitor the unknown ZZS as well.

7.7 Reflection by M. Kranendonk and S. Gabizon

Respectively, Health and Environment Policy Advisor and Managing Director of the Women Engage for a Common Future Foundation (WECF)

WECF – Women Engage for a Common Future – is committed to achieving a sustainable circular economy and to strengthening the role of women in that context.

An essential condition for the circular economy is that health interests must always be given priority over the economic benefits of recycling. Recent examples have also shown that recycling products that contain harmful ZZS may appear environmentally sound, but still poses unacceptably serious health risks. This has been determined from examples of toys that were made with plastic from electronic waste, containing hazardous substances such as flame retardants that exceeded the maximum value. Another example is the risks of using rubber granules made from old car tyres to produce infill for synthetic turf fields for playing football. Prevention is the keyword when coping with ZZS in the circular economy. The precautionary principle should certainly apply here if we have not yet achieved a clear understanding of all the effects on human health and the environment.

WECF always emphasises that standards, legislation and enforcement should be aimed at preventing exposure of the most sensitive groups, i.e. pregnant women and unborn babies, as well as children in general. There is increasingly clear scientific proof that even minute amounts of ZZS can have a harmful influence on the development of unborn babies and young children. There is also a difference between exposure effects in men and women. Preventive legislation and standards to be imposed if ZZS are potentially allowed into the circular economy must therefore take into account the sensitivity of the most vulnerable groups and the specific gender differences in health effects.

This preventive policy also requires that the government ministries responsible for the environment and for public health have arranged for sufficient expertise to guarantee these priority interests of protecting the environment and public health when drawing up regulations and standards and measures for their monitoring and enforcement.

In principle, we are convinced that public health interests warrant exclusion of ZZS from the circular economy, and that re-use of products containing ZZS can only be permitted if new products cannot in any way
expose the population to those substances. This also applies to workers in the re-use sectors.
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References

1. ARN; 2019; Aandrijfbatterijen (webpage); Consulted: November 2019; URL: https://arn.nl/autorecyclingketen/aandrijfbatterijen/.


4. DCMR Milieudienst Rijnmond; 2019; Luchtmeetnet DCMR (webpage); Consulted: November 2019; URL: https://www.dcmr.nl/projecten/luchtmeetnet-dcmr.html.


6. ECHA; 2015; 2014 CMR Report; European Chemicals Agency (ECHA); CMR Report.

7. ECHA; 2017; ECHA proposes a restriction on lead compounds in PVC articles; Public Consultation; URL: https://echa.europa.eu/documents/10162/539caf1a-68c8-1b51-1026-58d15209a2fc.

8. ECHA; 2019a; Candidate List of substances of very high concern for Authorisation (webpage); Consulted: November 2019; URL: https://echa.europa.eu/nl/candidate-list-table.


11. ECHA; 2019d; ANNEX XVII TO REACH – Conditions of restriction.


22. Gezondheidsraad; 2018; Gevaarlijke stoffen in een circulaire economie. ; 2018/10; URL: https://www.gezondheidsraad.nl/documenten/adviezen/2018/05/15/circulaire-economie.

23. GO FAIR; 2019; FAIR Principles (webpage); Consulted: November 2019; URL: https://www.go-fair.org/fair-principles/.
24. Hofstra U; 2018; *Inventarisatie ZZS in afval*; SGS Intron; URL: https://lap3.nl/achtergrond/documenten/gevaarlijk/.
36. NRC; 2017; *Wat te doen met afgedankte elektrische-autoaccu’s? (webpage)*; URL: https://www.nrc.nl/nieuws/2017/05/31/wat-te-doen-met-afgedankte-elektrische-autoaccus-10719808-a1561018.
37. OECD; 2018; Toward a New Comprehensive Global Database of Per-and Polyfluoroalkyl Substances (PFASs): Summary Report on Updating the OECD 2007 List of per-and Polyfluoroalkyl Substances (PFASs); Organisation for Economic Co-operation and Development; Series on risk management; No. 39. Paris, France.

38. Ökopol, RIVM, Risk & Policy Alanysts (RPA) & Milieu Ltd; 2017a; Study for the strategy for a non-toxic environment of the 7th Environment Action Programme; European Commission; 7th Environment Action Programme.

39. Ökopol, RIVM, Risk & Policy Alanysts (RPA) & Milieu Ltd; 2017b; Sub-study b: Chemicals in products and non-toxic material cycles; European Commission; 7th Environmental Action Programme.

40. Oomen AG & Groot GMd; 2016; Beoordeling gezondheidsrisico's door sporten op kunstgrasvelden met rubbergranulaat; RIVM; Briefrapport; 2016-0202; URL: https://www.rivm.nl/publicaties/beoordeling-gezondheidsrisicos-door-sporten-op-kunstgrasvelden-met-rubbergranulaat.


42. Poorter Ld & Leeuwen Lv; 2016; Zeer Zorgwekkende Stoffen: prioriteringsopties voor beleid; RIVM; Briefrapport; 2016-0122; URL: https://www.rivm.nl/publicaties/zeer-zorgwekkende-stoffen-prioriteringsopties-voor-beleid.


46. Rijksoverheid; 2019a; elektronisch Milieujaarverslag (e-MJV) (webpage); Consulted: November 2019; URL: https://www.e-mjv.nl/.

47. Rijksoverheid; 2019b; Emissieregistratie (webpage); Consulted: November 2019; URL: http://www.emissieregistratie.nl/epubliek/bumper.nl.aspx.


51. Rijkswaterstaat; 2019a; *Landelijk Afvalbeheerplan 3 (webpage)*; Consulted: November 2019; URL: [https://lap3.nl/](https://lap3.nl/).


56. RIVM; 2019c; *Lijst Zeer Zorgwekkende Stoffen (webpage)*; Consulted: November 2019; URL: [https://rvszoeksysteem.rivm.nl/ZZSlijst/Index](https://rvszoeksysteem.rivm.nl/ZZSlijst/Index).


59. RIVM & VeiligheidNL; 2019; *Waarzitwatin (webpage)*; Consulted: November 2019; URL: [https://waarzitwatin.nl](https://waarzitwatin.nl).


64. Verschoor AJ, Bodar CWM & Baumann RA; 2018; Verkenning milieueffecten rubbergranulaat bij kunstgrasvelden; RIVM; Briefrapport; 2018-0072; URL: https://www.rivm.nl/publicaties/verkenning-milieueffecten-rubbergranulaat-bij-kunstgrasvelden.

65. Wachholz C, Arditi S & Santos T; 2017; Keeping it Clean: How to Protect the Circular Economy from Hazardous Substances; European Environmental Bureau (EEB); EEB Report; URL: https://eeb.org/library/keeping-it-clean-how-to-protect-the-circular-economy-from-hazardous-substances/.


68. Wettenbank Overheid; 2019; Activiteitenbesluit milieubeheer; URL: https://wetten.overheid.nl/BWBR0022762/2019-10-01.

69. Zeng X & Li J; 2013; Implications for the carrying capacity of lithium reserve in China; Resources, Conservation and Recycling, 80, 58-63.

