

A Work Project, presented as part of the requirements for the Award of a Master's degree in Impact Entrepreneurship and Innovation from the Nova School of Business and Economics.

HOW CAN CIRCULAR ECONOMY CHANGE THE PUBLIC PERCEPTION OF THE
CHEMICAL INDUSTRY?

JOHANNES GEORG BRUNO BUNSE

Work project carried out under the supervision of:

Professor Ricardo Zózimo

31/01/2024

Abstract: This study examines public perception of the chemical industry and investigates whether incorporating Circular Economy practices can enhance this perception. While existing research primarily addresses public attitudes towards chemistry in relation to education and chemical hazards, the link between the industry's products, sustainability practices, and public perception remains underexplored. This exploratory research, involving a survey of 123 participants, utilizes multilinear regression analysis to identify strategies the chemical industry can adopt to mitigate public stigmatization. The findings highlight the potential for sustainability initiatives like Circular Economy to positively shift public attitudes and suggest avenues for industry engagement and communication.

Keywords: Chemical Industry • Circular Economy • Sustainability • Chemophobia • Public Perception

This work used infrastructure and resources funded by Fundação para a Ciência e a Tecnologia (UID/ECO/00124/2013, UID/ECO/00124/2019 and Social Sciences DataLab, Project 22209), POR Lisboa (LISBOA-01-0145-FEDER-007722 and Social Sciences DataLab, Project 22209) and POR Norte (Social Sciences DataLab, Project 22209).

Introduction

One of the main solutions trying to fight climate change and limit waste generation is the principle of circular economy. This principle suggests a reuse of resources with a strong link to sustainability (Geissdoerfer, Savaget und Evans 2017). According to Kirchherr, Reike and Heikkert (2017), Mhatre et al. (2021), and Schut, Crielaard, and Mesman (2015) the following is the most common understanding of circular economy “It replaces the ‘end-of-life’ concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models” (Ellen MacArthur Foundation 2012, p.7).

As a consequence, many global nations and conglomerations have then formulated a plan to establish circular economy in their legislations. The EU included circular economy as one of their main strategies in the European green deal and published a detailed action plan for companies to act on circular economy (European Commission 2020). As part of the EU taxonomy, companies need to report on circular economy matters (European Commission 2020). In 2021, also China released a new development plan regarding their circular economy strategy that promotes recycling and renewable products (R. Chen, China's Circular Economy Transition: Challenges and Solutions Ahead 2023).

This then results in a growing interest in the industries of the strategy circular economy. Especially in the chemical industry, where the utilization of waste materials, especially plastics, as feedstock is gaining significant attention, this implied being able to reduce environmental impacts as well as raw material costs (Somoza-Tornos, et al. 2020). While circular economy practices are connected to complex industrial processes, the chemical industry is set to be a key contributor to tackling, this challenge. According to the president of the Chemical Industry Association, the chemical industry

is convinced to already making important contributions to challenges of the future such as circular economy (VCI 2021).

On the one hand sustainability and circular economy tend to have a positive perception, either implied through climate change or through general conviction Martin (2010), Guo and Huang (2023) and Agentur für Forschung (2019). On the other hand, we can see a rather negative perception of the chemical industry and chemicals. A common aversion towards chemistry developed, known as chemophobia, that the public has towards chemicals (Rollini, Falciola und Tortorella 2022). The term Chemophobia captures the essence of the public's fear when it comes to chemical products. The International Union of Pure and Applied Chemistry (IUPAC) defines it as an "irrational fear of chemicals," highlighting the anxiety that surrounds the use of these substances (Duffus, Nordberg und Templeton 2007). Djerassi (2004) points out the common lack of knowledge about chemicals among most people and their tendency to see chemicals as either completely safe or completely unsafe.

But why is it important to look at public perceptions? Already in 2006 it is suggested that the societies image of the chemical industry has direct influence on the industries success. Sahm (2006) states that the chemical industry's image is very crucial, whereas Lin, Lee and Wang (2021) find that a general positive perception of sustainability can in fact increase the sense of community.

Taking it one step further, with its role as a key contributor to fight climate change and implement key practices such as circular economy, the broad research question arises: "How can circular economy change the public perception of the chemical industry?" To better understand these phenomena, this study explores the literature to further understand the public perception of the chemical industry as well as its link to circular economy practices followed by a survey addressing the research question.

Building on Bearth, Saleh and Siegrist's (2019) identification of a research gap in the experimental investigation of public stigmatization towards chemicals, this thesis employs a survey-based exploratory approach. While not experimental, the survey seeks to understand if the perception of the chemical industry can be positively influenced by the principles of circular economy. The insights gained are intended to inform future experimental research, potentially guiding communication strategies to reshape public understanding and acceptance of chemicals, with practical implications for the industry and policymakers.

The report is organized as follows. The next section explores different perspectives of the literature regarding the public perception of chemistry as well as the corresponding connection to circular economy. Then, chapter three consists of the methodology, followed by the findings in chapter four and discussion in chapter five and a conclusions in chapter six. Lastly, the limitations and directions for future research are displayed in chapter seven.

2. Literature Review

2.1 Public perception: Education

The public's understanding of the chemical industry is complex, with a mix of confusion and caution. A survey by VCI (2021) included 140 detailed conversations and 1,500 online surveys, and showed that people have varied opinions about the industry. This complexity is even more evident when comparing the public's better understanding of the pharmaceutical side of the industry to their more general view of the broader chemical sector, often seen only as big factories and smokestacks (Sahm 2006).

This lack of clear understanding often starts in school, where many students find chemistry hard, and this difficulty continues into adulthood. VCI (2021) further notes that this gap in education helps create a distance between the public and the chemical industry, possibly leading to a fear of

chemicals known as chemophobia. This is supported by Sahm (2006), further emphasizing how also the parents view on science and technology can influence attitudes towards science.

In RSC's (2015) study with 2,104 participants, 76% thought of chemists mainly as working in pharmacies, showing a narrow view of the field. Additionally, more than half of the respondents felt unsure about discussing chemistry, highlighting a general lack of knowledge. This study also found that most people think of chemicals as synthetic and harmful, and they don't feel well-informed about them (RSC 2015). This points to the need for better education to improve people's knowledge and ability to make informed choices (Bearth, Saleh und Siegrist 2019).

Education is key in shaping how people view the chemical industry. In less developed countries, not knowing about the dangers of chemicals is a big risk (Djerassi 2004). In wealthier countries, even those in charge often don't understand chemistry well, leading to the risk of poor decision-making and regulation of the industry (Palermo 2018). Teaching the public about the principles of toxicology is important to reduce irrational fears and help people make better decisions (Bearth, Saleh und Siegrist 2019).

2.2 Public Perception: Risk Perception

The public's perception of risks associated with chemicals and chemical industry projects is highly fragmented. Laypeople tend to view these risks in binary terms, often categorizing them as either completely safe or entirely dangerous. In contrast, experts understand that the reality is more complex, with risk levels varying depending on specific circumstances (Dement and Lucia 2022). This disparity in perception is particularly evident in the context of biotechnology, where the general public may overlook the potential benefits, focusing instead predominantly on the possible risks (Fuchs and Gzásó 2014).

In the example of the petrochemical industry Bustamente Picón et al. (2023) find that 63% of participants think of the industry as very hazardous. A further finding is a different risk perception

between gender and age (Bustamente Picón, et al. 2023). This emphasizes the complexity to capture the general opinion about the chemical industry in society.

2.3 Chemophobia

Moreover, the public's concern primarily focuses on synthetic chemicals and their potential toxicity, even though the toxicity of a chemical is not determined solely by whether it is natural or synthetic (Dement und Lucia 2022). Some of the most harmful chemicals are naturally occurring, while many synthetic chemicals are least toxic (Entine 2011). Additionally, the preference among the public for natural over synthetic substances, despite the lack of scientific basis for such a distinction, is well documented (Entine 2011).

The public's negative perception of chemistry and chemicals can be partly explained by the media's tendency to overemphasize chemical accidents, often overshadowing significant advancements in science and technology (Rollini, Falciola und Tortorella 2022). A potential timeline of notable chemical accidents, illustrate how these incidents have potentially contributed to the rise of chemophobia (Appendix 1). Further, media coverage often strips these events of their local context, elevating them to national concerns and thus, complaints for changes across the entire industry arise (Dement und Lucia 2022).

As the chemical industry has grown, so has public awareness, with the industry's growth seemingly mirroring the rise in public concern (Dement und Lucia 2022). These chemical incidents have led to a increasing societal trend of chemophobia, characterized by a general aversion or fear of chemicals, often rooted more in emotion than in scientific understanding (Dement und Lucia 2022). This has resulted in a society increasingly cautious about chemicals and science at large, often advocating for the removal of many beneficial and difficult to replaceable chemicals from the market, even in the absence of substantial evidence of risk. This caution leads to the point where replacement substances, often untested, are favored (Entine 2011).

2.3 Public Perception: Innovation

On the other hand, VCI (2021) finds the industry is displayed as being able to create something new through their innovation potential, therefore being able to tackle global problems as the climate change. Although, 80% of the participants stated the industry as only wanting to create something new and tackle global challenges as far is largely profitable, the chemical industry is perceived as an absolute necessity that impacts all life. Participants realize their dependence on the Chemical Industry (VCI 2021).

Accordingly, RSC (2015) finds that 72% of the participants agreed that chemistry makes a substantial contribution to the economic growth in the UK. Taking another angle by looking at the perception of chemists, it can be observed, that they are viewed very positively. 95% thought they make a difference in the world, while 93% were viewing them as honest and 88% as approachable (RSC 2015). Also looking back at a study done in Germany in 2004 about the chemical industry, 60% answered with having a positive opinion (Sahm 2006).

Another viewpoint can be given looking at a recent study from twitter (now X). After analysing a total of 256,833 tweets, that have been filtered down to 50,725 tweets, Guerris, et al. (2020) display that for chemistry, chemical and chem, a higher percentage of positive than negative tweets was obtained. While this confirms, that in many chemophobia is still present, the majority stated that chemistry was part of the solution rather than the problem (Guerris, et al. 2020).

Hence, the fragmentation of the public perception of the Chemical Industry can be observed with these examples. While having irrational fears of chemicals, participants also view the Chemical Industry as a necessity for life.

2.4 Link to Circular Economy

How does Circular Economy link to the varied view on chemicals? Circular Economy already plays a role a various sectors, including environmental conservation, mobility, nutrition, textiles, and

electronics (R. Chen, China's Circular Economy Policies: Review and Reflection 2023). Also, in the chemical industry, a significant focus is on mechanical and chemical recycling methods (Payne und Jones 2021). An emerging area of interest is the recycling of black mass, a key component in battery recycling. This process is vital for extracting and reusing metals from spent batteries, thereby completing the recycling loop for batteries (Brudermüller 2020). Such practices are integral to the chemical industry's contribution to sustainable development.

Blok et al. 2016 finds, that in comparison to the standard 'business as usual' approach, there is a significant CO₂e emissions gap of 26 billion tons. Current climate policies, including those committed to under the Paris Agreement, are projected to reduce emissions by 11-13 billion tonnes CO₂e. Circular economy strategies have the potential to substantially mitigate the remaining emissions gap, potentially addressing about half of it. This highlights the crucial role of circular economy practices in global efforts to reduce carbon emissions. For a more detailed view please have a look at Appendix 2.

Furthermore, Ellen MacArthur Foundation, Sun, McKinsey Center for Business and Environment (2015) reveal that embracing a circular economy, propelled by technological advancements, offers Europe the opportunity to enhance resource productivity by up to 3 percent annually. This could lead to a primary resource benefit of approximately €0.6 trillion per year by 2030 for European economies. Beyond resource savings, the circular economy is expected to yield €1.2 trillion in non-resource and externality benefits, culminating in total annual benefits of around €1.8 trillion compared to current levels. These findings, reported in 2015, underscore the substantial economic and environmental advantages of transitioning to a circular economy model (Ellen MacArthur Foundation, Sun, McKinsey Center for Business and Environment 2015).

Zhang, et al. (2022) discover that consumers' willingness to participate in circular economy practices is influenced by several factors. When consumers anticipate positive outcomes and

perceive social support for their actions, their willingness to engage increases. However, if they expect the effort required to be high, their willingness decreases. Conversely, the consumer industry holds expectations for the chemical industry to improve recycling processes and increase the use of recyclable materials (VCI 2021). Rigall and Wolters (2019) analysed key recommendations from industry experts, where ten central recommendations were identified for the chemical industry, with two of them specifically addressing aspects of the circular economy.

3. Methodology

3.1 Research Industry

The chemical industry has been a pivotal part of global economic development, representing one of the most diverse economic sectors with numerous sub-sectors. It encompasses a wide variety of raw materials, substances, and complex chemical processes, essential in areas such as agriculture, nutrition, automotive, and pharmaceuticals. Virtually no industrial process exists without reliance on chemicals (Boyanov 2020).

Due to its high production volume, the chemical industry is notably energy and resource-intensive. Large quantities of basic chemicals are required to produce essential chemicals, as detailed in Appendix 3, which explains the workings of the chemical industry (Lenz und Lafrance 1996).

Globally, the chemical industry is evolving, with a growing focus on sustainability, changing consumer tastes, and the influence of activist shareholders. This shift is evident in the biochemical industry, which alone is worth €40 billion and provides over 90,000 jobs (Alessandrini, et al. 2017).

However, the industry, while not an end-customer branch and situated early in the supply chain, faced significant challenges during the pandemic due to disrupted supply chains. This led to overordering of supplies in 2021 and 2022, and a subsequent period of destocking in 2023, prompting many companies to focus on cost-cutting (Deloitte 2023).

Thus, it can be noticed, that each of the global players in the chemical industry now faces different challenges that need to be overcome. The European chemical industry is currently experiencing a recession, with chemical capacity utilization dropping to 55% in May 2023, a significant decrease from the average of 80% since 1997 (Hodges 2023).

Furthermore, the future of the chemical industry is marked by uncertainty due to increased regulation. The Chemical Strategy for Sustainability (CSS), part of the EU Green Deal introduced by EU Commissioner in 2012, imposes stricter requirements than the current REACH regulation. This poses particular challenges for small and medium-sized companies due to the financial burden of meeting these data requirements (Johansen, et al. 2021; Rönisch and Uebele 2023).

China's chemical industry, with sales of around \$1.5 trillion in 2017, has been the world's largest since 2011, contributing significantly to global chemical market growth over the past two decades (Hong, et al. 2019). However, this rapid growth has also led to safety issues, pollution, ecological and environmental problems, high energy consumption, and excess manufacturing capacity Chen and Reniers (2020). In the United States, advantageous raw material prices continue to bolster global competitiveness, with brisk exports expected, contingent on sustained offshore demand. However, inflation has impacted consumer spending power (Tullo 2023).

3.2 Data Collection

At the outset of this thesis, the initial focus was on exploring the role of sustainability in revitalizing the European chemical industry. As the literature review on sustainability progressed, the topic was further refined to a more specific and highly relevant subcategory: Circular Economy. This area is not only crucial to the chemical industry but also significantly pertinent to addressing the primary challenge of climate change. Further research into the European chemical industry revealed a particularly intriguing aspect: the public perception of the industry. It became evident that public perception is closely linked to the industry's success, a connection first noted by Sahm in 2006.

This realization led to the evolution of the research question: How can Circular Economy change the public perception of the chemical industry?

To investigate this, the initial plan was to utilize existing datasets on Circular Economy and public perception related to the chemical industry, focusing on recent and relevant data. However, a thorough search revealed that no available dataset sufficiently met the criteria in terms of recency and alignment with the research question. Consequently, the decision was made to design an original questionnaire to gather the necessary data.

This approach allowed for the collection of targeted information directly related to the research question, ensuring that the data was both current and specifically relevant to the intersection of Circular Economy and public perception within the context of the European chemical industry.

Looking at the distribution, the survey was distributed using online and personal networks to ensure a broad and diverse range of respondents. The primary method of distribution was through social media platforms and messaging applications. Therefore, I could make use of both my personal network and those of close contacts to ensure reaching a wide audience. This approach included sharing the survey at different institutions ranging from high schools to universities and workplaces.

This approach guaranteed to include a range of cultural and international perspectives. The distribution strategy was designed to capture a different age group, different education levels, genders, and cultural contexts. The survey was conducted mainly online, facilitating easy access for participants, and enabling the inclusion of a geographically diverse audience. In addition to the primary online distribution, an exception was made to accommodate participants from a senior home who lacked online access. For these individuals, a printed version of the survey was provided. The responses from these printed surveys were subsequently integrated into the overall data pool

to ensure their inclusion in the analysis. Participation was voluntary, with respondents informed about the purpose of the study and assured of their anonymity.

3.3 Questionnaire Design

The questionnaire for this study adopts the framework established by He et al. (2018) to explore public perception of the chemical industry. This research is guided by the further research question proposed by Bearth et al., focusing on investigating the public stigmatization of the chemical industry. While Bearth et al. suggested an experimental approach for future research, this study employs an exploratory approach. The success of this thesis hinges on the honest and insightful contributions of survey participants. Previous surveys capturing public perception of the chemical industry, such as those conducted by RSC (2015), Sahm (2006), and He et al. (2018), provide a foundation for this research.

This study adapts a similar set of questions from these prior studies, merging and modifying them to align with the specific research questions related to circular economy. The questionnaire structure mirrors that of He et al. (2018), encompassing four main sections: First, socio-demographic characteristics of respondents, including age, income, and education; Second, knowledge and perceived environmental impacts and awareness of Chemical Industrial Parks, Thirdly, information disclosure and participation in CIP decision-making, encompassing sources of information, media roles, and stakeholder trust levels; and in the fourth part attitudes towards new Chemical Industrial Parks, reasons for support or opposition, and measures to enhance acceptance. A 7-point Likert scale was utilized to capture respondents' views on the impacts and benefits of Chemical Industrial Parks, as well as their acceptance of these projects.

To ensure the study's relevance, its design incorporates elements from previous successful surveys. The questionnaire includes basic knowledge questions about sustainability and circular economy, which are beneficial for clarifying and organizing the survey content and aiding in the development

of self-assessment skills for participants (Wirth und Perkins 2005). These questions are structured as multiple-choice questions, with one correct option and three incorrect alternatives. Other questions in the survey allow for multiple responses, capturing perceived benefits of a battery recycling chemical industrial park and sources of information about the chemical industry.

3.4 Data Analysis

In this study, RapidMiner was utilized for data analysis, facilitating both correlation and multilinear regression analyses. Initially, the dataset underwent a cleansing process. This involved the exclusion of incomplete survey responses, ensuring the integrity and completeness of the data used for analysis. Additionally, a validity check led to the exclusion of one respondent who claimed to be under 20 years old with a PhD. Out of the original 133 responses, 123 were deemed suitable for analysis. The survey was collected at about a time frame of one month between the first of November and the first of December.

To enable effective processing in RapidMiner, the data required conversion into a quantitative format. Following the approach of He, et al. (2018) the 7-point Likert scale responses were numerically encoded, with values ranging from 1 to 7. The multiple-choice knowledge questions, as well as the clustered origin and gender questions, were transformed using binary coding, where '1' indicated a correct response and '0' an incorrect one. Additionally, certain questions that did not contribute to the analysis, specifically informative follow-up questions with multiple answers, were omitted from the dataset for the regression analysis (Liu, Qian und Wang 2023).

The original questionnaire comprised 18 questions. However, due to a technical issue, the question "How do you view Chemical Industrial Parks?" displayed only six of the intended answer options. Consequently, this question was excluded from the dataset to maintain the accuracy and reliability of the analysis.

Subsequent to these preparatory steps, the study proceeded with a correlation analysis and multilinear regression to examine the relationships and dependencies within the data. The complete Survey Catalogue can be found in Appendix 4 and 5.

4. Results

4.1 Descriptive Results

Item	Status	Percent (%)	Item	Status	Percent (%)	Item	Status	Percent (%)
Gender	Male	61	Origin	Albania	0,81	Income	below 20,000€	51,2
	Female	37,4		Austria	1,63		20,000€ - 40,000€	9,8
	Diverse	0,8		Canada	2,44		40,000€ - 60,000€	8,1
	Prefer not to say	0,8		Germany	79,67		60,000€ - 80,000€	8,9
Age	<20	8,9		Italy	0,81		above 80,000€	22,0
	20-29	54,5		Luxembourg	0,81		Education	Less than high school
	30-39	5,7		Netherlands	2,44	High school graduate		30,9
	40-49	4,9		Philippines	1,63	Apprenticeship		9,8
	50-59	19,5		Slovakia	0,81	Bachelor's degree		35,0
	60-69	4,1		South Africa	1,63	Master's degree		21,1
	>69	2,4		Spain	0,81	PhD		2,4
		Switzerland		1,63				
		UK		0,81				
		United States		2,44				
		Vietnam		0,81				
		Zimbabwe		0,81				

Table 1: Socio-Demographics

In examining the socio-demographic profile of survey respondents, it was found that a majority (61%) are male, with the most common age group being 20-29 years. Table 1 shows, that 35% possess a Bachelor's degree and approximately 31% have a

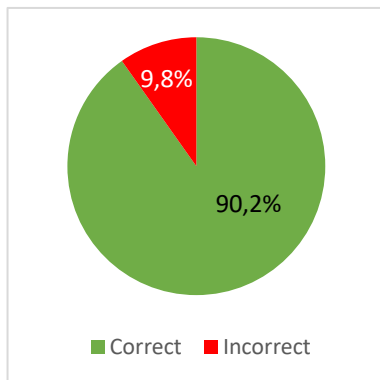


Figure 1: Knowledge Circular Economy

high school diploma as their highest level of education. The income distribution reveals that over half of the participants (51,2%) earn less than 20,000€ annually, and a majority (79,67%) are from Germany.

Moving to the multiple-choice questions, a high proportion of respondents 90,2% accurately recognized that repairing, reusing, and recycling products, instead of disposing of them, is a key principle of circular economy (Figure 1). (92,7%) correctly identified that water is composed of two hydrogen atoms and one oxygen atom. Similarly, 90,2% accurately (92,7%) correctly identified that water is composed of two hydrogen atoms and one oxygen atom (Figure 2).

The participants' interest in sustainability (Figure 3), measured on a 7-point Likert scale, averages at 5,04, with 46,3% indicating a moderate level of interest (rating 5 out of 7). In contrast, interest in the chemical industry scores lower, with an average of 3,25. The most common response was a “barely interested“ (2/7). Sources for chemical industry information predominantly include

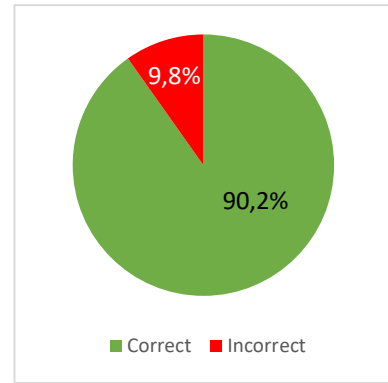


Figure 2: Knowledge Circular Economy

television/online news (78%), newspapers (41,5%), and social media platforms like Instagram, Facebook, and TikTok (31,7%), with respondents allowed to select multiple options (Appendix 6). Regarding trust in the media to provide accurate information about the chemical industry, responses varied, averaging at 4,26 on the Likert scale (Appendix 7). The most frequent response (26,3%) was a moderate level of trust (5/7), while about 31% expressed distrust (combining ratings 1, 2, and 3 out of 7).

Analysis of responses to various scenarios about the construction of a Chemical Industrial Park (CIP) revealed diverse opinions (Figure 4). In the base scenario of a CIP being built within 5 km (from now on CIP 5km), approximately 70% expressed negative views (1,2,3/ 7), with 27,6% specifically indicating a negative stance (2/7). The average response was 2,89. For the scenario of

a CIP within 100 km (from now on CIP 100km), the neutral view (rating 4 out of 7) was predominant (43,9%), averaging at 4,33. In this case, no respondents selected a very negative

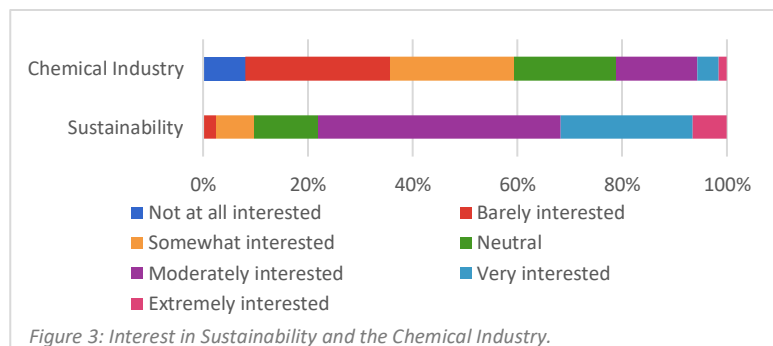
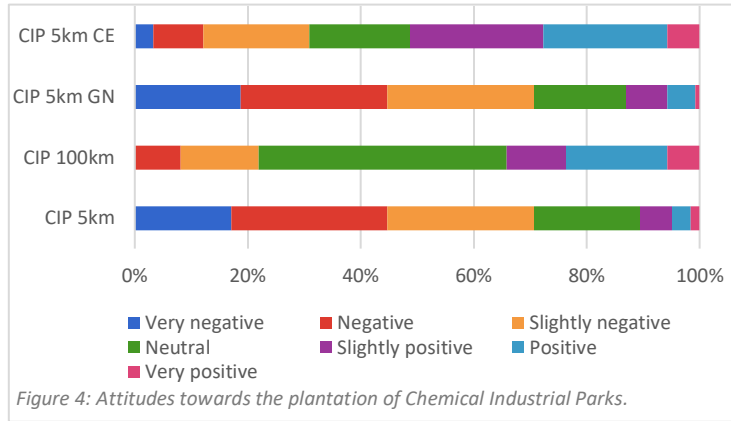


Figure 3: Interest in Sustainability and the Chemical Industry.

view and in total about 22% expressing negative opinions (1,2,3/ 7). In the scenario of a government-built CIP within 5 km (from now on CIP 5km GN), 18,7% indicated a very negative view (1/7), with an overall negative sentiment from about 71% (1,2,3/7) and an average response

of 3,08. When asked about the change in concern level if provided with home test kits, 26,8% reported a moderate decrease in concern (3/7), while 17,1% indicated an increase in concern (6/7), with an overall average response of 3,98 (Appendix 7).



In the final scenario, focusing on a CIP promoting a circular economy project via a battery recycling factory (from now on CIP 5km CE), 51,5% of the participants had a positive reaction (ratings 5, 6, and 7 out of 7), in contrast

to 31% who viewed it negatively (1,2,3/ 7), resulting in an average response of 4,38. Lastly, the factors influencing the change in opinion were predominantly environmental benefits (63,4%), followed by transparency (39%) and economic benefits (25,2%) also visible in Appendix 8.

4.2 Correlation Results

This section presents the findings from the correlation analysis aimed at exploring the impact of various factors on public perception of the chemical industry. Defined by Cohen (1988) the most pertinent correlations, specifically those indicating medium (correlation above 0.3) and large (correlation above 0.5) effect sizes, are highlighted here, with the complete correlation matrix available in Appendix 9.

A notably large effect size is observed between the variables Male and Female (-0,97). This is attributable to the dummy encoding method employed for gender categorization. Due to the minimal representation of participants identifying as 'diverse' (0,8%) and 'prefer not to say' (0,8%), the dummy variables essentially represent the same attribute but are inversely correlated. Male is coded as '1' for yes and '0' for no, while 'Being Female' is coded as '1' for yes and '0' for no. Consequently, this high negative correlation is explained and has been excluded from the

regression analysis to avoid multicollinearity Skrivanek (2009) and Tsoumakas and Katakis (2009). Additionally, large effect sizes are evident among the dependent variables. There exists a very strong correlation (0,89) between CP 5km and CP 5km GN, and significant correlations between CP 5km and CP 100km (0,57), as well as between CP 5km GN and CP 100km. A notable correlation (0,54) is present between the age range of participants and their 'Gross Annual Income'. Regarding medium-sized effects, correlations are observed between the Male (0,31) and Female (-0,39) variables with CP 5km, as well as between Male (0,32) and Female (-0,38) with CP 5km GN. A moderate correlation (0,48) is noted between Education and Income, and between Education and Age (0,40) and a medium effect size is also seen between the interest in the Chemical Industry and interest in Sustainability (0,37). Furthermore, a correlation of 0,33 is observed between identifying as 'Central European' and trust in the media's accuracy regarding the chemical industry. Finally, regarding Central European (from now on CE) participants, who constitute approximately 83% of the sample, medium-sized correlations are noted with other regions. Due to regional clustering and dummy encoding (with '1' indicating origin from a specific region and '0' otherwise), there are negative correlations with South European (CE -0,44), Western European (CE -0,44), North American (CE -0,49), African (CE -0,34), and Asian (CE -0,34).

4.3 Regression Results

Item	Variable	Coefficient	Std. Error	Std. Coefficient	Tolerance	t-stat	p-Value	Significance
CIP 5km	Gender	0,871	0,298	0,309	0,960	2,924	0,005	***
	Trust Media	1,470	0,585	0,266	0,913	2,512	0,014	**
CIP 100km	Knowledge Chemistry	-1,116	0,570	-0,225	1,000	-1,960	0,054	*
	Trust Media	1,161	0,636	0,213	0,974	1,826	0,072	*
CIP 5km GN	Gender	0,841	0,310	0,283	0,940	2,714	0,008	***
	Trust Media	2,079	0,609	0,357	0,929	3,416	0,001	***
CIP 5km CE	Age	-1,430	0,822	-0,237	0,993	-1,741	0,086	*
	Interest Sustainability	1,759	0,918	0,241	0,984	1,916	0,059	*
	Trust Self-Test	-1,449	0,686	-0,245	0,966	-2,111	0,038	**

R-Squared *CIP 5km:* 0,310 *CIP 100km:* 0,163 *CIP 5km GN:* 0,328 *CIP 5km CE:* 0,137

* for p<0,1 ** for p<0,05 *** for p<0,01

Table 2: Interest in Sustainability and the Chemical Industry.

Building upon the established correlations, four multilinear regression analyses were conducted to assess the predictive power of various variables on different perspectives towards Chemical Industrial Parks. Specifically, these perspectives include opinions on constructing the CIP 5km, CIP 100km, CIP 5km GN and CIP 5km CE. For this analysis a significance level of $p < 0,1$ was chosen due to its sample size and exploratory approach (Kim und Choi 2019).

Initially, the fourth dependent variable, CIP 5km GN was considered. However, due to its substantial correlation (0.89) and parallel results with the first scenario, it was not included in this study. Furthermore, as identified in the correlation analysis, the variable 'female' was omitted due to significant multicollinearity (-0.97) resulting from dummy encoding. To mitigate multicollinearity and the overlap of dummy variables, the diverse and prefer not to say categories (both at 0.8%) were also excluded. This was necessary as their inclusion dramatically increased the standard error. Consequently, being male is the only gender-related variable included in the models. For the variable of origin, only Central European was retained, as the inclusion of other regionally-encoded variables interfered with model significance and inflated the standard error (Liu, et al. 2019).

Further, Table 2 presents the findings from the first linear regression analysis. This model accounts for 31% of the variance ($R^2 = 0.31$) in public opinion about constructing a CIP within 5km, indicating a medium effect size. The significant predictors identified are 'being male' ($p = 0.005$) and trust in the media's accuracy regarding the chemical industry ($p = 0.014$).

In addition, Table 2 details the results of the second linear regression analysis, which explains 16.3% of the variance ($R^2 = 0.163$) in public opinion about building a CIP within 100km, suggesting a smaller effect size. The significant predictors in this model include the chemistry knowledge question ($p = 0.054$) and trust in the media ($p = 0.072$).

Lastly, Table 2 summarizes the outcomes of the third linear regression analysis. This model explains 13.7% of the variance ($R^2 = 0.137$) in opinions regarding a CIP promoting circular economy projects within 5km, indicating a medium effect size. The statistically significant predictors are the participants' age range ($p = 0.086$), their interest in sustainability ($p = 0.059$), and trust when provided with a self-test kit ($p = 0.038$). A complete overview of the regression analysis can found in Appendix 10.

5. Discussion

In this section, the main findings will be analyzed more closely. This study primarily investigates how the increasing focus on sustainability in particular Circular Economy might influence public perception of the chemical industry. The initial scenario revolves around attitudes towards a Chemical Industrial Park (CIP) located 5 kilometers away. Consistent with what has been mentioned by Dement and Lucia (2022) earlier, the chemical industry often faces a fragmented and generally negative public perception, which is supported by this research. The average rating for the CIP 5km is 2.89 out of 7, with 70% of responses showing a negative view (ratings 1, 2, or 3 out of 7), and 27.6% choosing a rating of 2 out of 7.

An interesting finding is the significant relationship between being male and a more favorable view of the CIP 5km (coefficient = 0.871, $p = 0.005$). This differs from He, et al. (2018), who did not find a significant link between gender and support for a nearby CIP. They did, however, find connections with education, information, and trust. In this study, unlike He, et al. (2018), no correlation was found between education level and acceptance of the CIP.

Nevertheless, Fuchs and Gzásó (2014) find similarities in how gender influences support for scientific developments like nanotechnology, where being male often correlates with more support. This aligns with this finding for the CIP 5km. RSC (2015) also notes gender differences in attitudes towards chemistry, with men generally more positive and comfortable discussing it. This study

partially supports this, although the link between gender and interest in the chemical industry is not strong (correlation = 0.12).

Another significant observation is the positive link between supporting the CIP 5 km and trusting the media (coefficient = 1.47, $p = 0.014$), in line with He et al. (2018). Most of the participants moderately trust the media to accurately report on the chemical industry. The primary sources for their information are television/online news, newspapers, and social media. This mirrors RSC's (2015) findings about people turning to television and online news for information on chemistry. This study also notes that while many trust these media sources, there is also a significant portion that does not. This skepticism might be due to the media's tendency to sensationalize chemical incidents, overshadowing progress in science and technology (Rollini, Falciola und Tortorella 2022). Moreover, the growing mistrust in scientific expertise, as highlighted by Boele-Woelki, et al. (2018), might also be contributing to this mixed trust in media.

According to Preciadoa, et al. (2012) and Mirandal and Claudel (2021), various social studies have demonstrated that distance is a significant factor for individuals, with proximity being closely linked to perception. Hence, this study examines participants' perceptions of constructing a CIP within 100 kilometers.

Participants' average score increased from 2.89 for a CIP within 5 kilometers to 4.33 for one within 100 kilometers. This increase suggests that individuals indeed perceive the risks associated with CIPs as lesser when these are situated further away.

Additionally, He et al. (2018) investigated public acceptance of distant CIPs and identified gender, education, trust, and participation as significant variables. In this study, knowledge, as measured by the multiple-choice question about water's chemical composition (coefficient = -1.116, $p = 0.054$), and trust in media (coefficient = 1.161, $p = 0.072$) emerged as significant. The variable

'trust' thus maintains its significance across both studies and is also observed in the regression analysis for the CIP within 5 kilometers.

The finding of knowledge being negatively correlated with the acceptance of a more distant CIP, while not observed with a proximate one, has not been previously reported. Xu et al. (2023) notes differences in risk perception, where closer proximity typically leads to higher perceived risk, but in scenarios like an epicenter, those closer to the epicenter are often less worried than those farther away. Further, experts tend to make decisions based on well-defined scientific research, in contrast to laypeople (Slovic, Fischhoff und Lichtenstein 1985). However, a definitive explanation for the observed negative correlation between knowledge and acceptance of CIP 100km, which is not present for more CIP 5km, is not available in the existing literature. However, the model's strength, as indicated by an R-squared value of 16.3%, does not suggest a high explanatory power. Nevertheless, this area presents an opportunity for further research to either validate or discard this finding.

Having examined the different attitudes towards CIP 5km and 100km, this research now shifts focus to understand the impact of an institutional aspect - governmental involvement. This aspect introduces additional complexity, extending the study's exploration of how institutional factors influence public perception.

He et al. (2018) establishes that government officials are often viewed as the most trusted stakeholders in the development of CIPs, with a trust level of 44%. Huang, et al. (2013) findings further indicate a link between trust in government and reduced risk perception regarding CIP construction. Consequently, it was anticipated that the average rating for government-involved CIP scenarios would be higher than those for the corresponding CIP 5 km scenario. Contrary to expectations, the average scores were nearly identical (2.89 for CIP 5 km and 3.08 for CIP 5 km

with government involvement). Additionally, the regression analysis yielded similar significant results and answer distributions for both scenarios, as indicated in Table 2.

This scenario, however, was not explored in greater detail in the results section, partly due to its high correlation coefficient (0.89). This similarity in responses might reflect varying levels of trust towards governments. Most participants in this study are from Germany, where a survey by forsa (2023) shows a low trust in politicians, ranking them among the least trusted professions at only 14%. This contrasts with the participant demographics in He, et al's (2018) and Huang, et al's (2013) studies, predominantly from China, where government trust tends to be significantly higher (Su, et al. 2016). In Germany, trust in the government reached a record low in 2023 at 27% (forsa 2023), while the average trust level in European Union governments stands at 37% (OECD 2021). These observations suggest that with the current sample size, the inclusion of governmental involvement as a factor in CIP development, while maintaining a 5km distance, does not significantly alter public perception. However, they open avenues for future research involving a more diverse participant base, potentially offering insights into how local trust levels in respective governments might influence perceptions of CIPs.

As the focus of this study shifts from the framework established by He, et al. (2018) to the relatively unexplored link between public perception of the chemical industry and circular economy principles, several key findings emerge. Rigall and Wolters (2019) highlight the consumer industry's recommendation for the chemical industry to prioritize circularity, waste reduction, and circular economy projects. Guo and Huang (2023) emphasize the need to explore metal recovery further, while Payne and Jones (2021) point out the often-overlooked social value of recycling practices, such as in plastics.

In light of these recommendations, this study probes participants' attitudes towards a Chemical Industrial Park (CIP) promoting focusing on battery recycling within 5 kilometers (CIP 5km CE),

assessing whether a transparent and sustainable approach brings more positive responses. The results show an average rating of 4,38 for the CIP 5km CE scenario, the highest among all scenarios examined, even marginally exceeding the average for the CIP located 100 kilometers away (4,33). This suggests that emphasizing transparency and sustainability can positively shift public attitudes towards a CIP in close proximity.

The multilinear regression analysis presents distinct results: the interest in sustainability (coefficient = 1.759, $p = 0.059$) is notably linked to attitudes towards the CIP 5km CE. This correlation may be explained by the European Union's focus on circular economy as a key sustainability topic in the coming years (European Commission 2020). Participants interested in sustainability likely perceive the benefits of such initiatives as outweighing potential risks.

Another significant finding is the negative association with age (coefficient = -1,43, $p = 0,086$). Correlation analysis shows that age range is related to gross annual income and education level. Older participants in this study, typically with more work experience and potentially higher income, displayed different attitudes compared to younger participants. Research by Hiroshima University (2021) indicates that individuals aged 18 to 30 are more inclined towards sustainable products and behaviors. This is given support by findings from Balunde, Perlaviciute and Truskauskaite-Kuneviciene (2020), highlighting that adolescents actively engage in sustainable practices, not just advocate for them. These trends imply that younger individuals in this study's demographic are more inclined towards sustainability, influencing their attitudes towards the CIP 5km CE.

Furthermore, following Djerassi's (2004) suggestion of using simple monitoring devices to alleviate concerns about proximity to the chemical industry, this study found a significant correlation between such devices and attitudes towards the CIP 5km CE (coefficient = -1.449, $p =$

0.038). The negative coefficient indicates that providing tools for independent verification can effectively reduce concerns about living near a CIP.

This emphasizes the chemical industry's need for transparency, as supported by Huang, et al.'s (2013) observation that more information about a CIP diminishes the impact of trust levels. Consistent with consumer industry recommendations, ensuring process transparency is crucial. Bearth, Saleh and Siegrist (2019) note that transparency can enhance trust, especially in the absence of knowledge about the chemical industry. Participants in this study predominantly changed their opinions due to environmental reasons (63.4%) and transparency (39%), with economic factors being less influential. This aligns with Lieder and Rashid (2015) findings that in the context of circular economy, environmental considerations often overshadow economic ones.

To sum up, these results demonstrate a clear shift in attitudes with the inclusion of transparency and sustainability elements in a CIP, maintaining consistent distance and enabling conditions. However, the public perception of the chemical industry is connected to a variety of societal paradigms. As Sahm (2006) notes, understanding and changing this image requires a deep understanding of the industry. While this work tries to unravel complexities in the context of circular economy practices, there is further potential to explore other aspects of the industry.

6. Conclusions

This study addresses the research gap of exploring the public stigmatization toward the chemical industry by investigating whether circular economy principles can positively influence public perception of the chemical industry. The literature reveals a highly fragmented public attitude towards this sector, influenced by factors such as education, chemophobia, and varying risk perceptions. The findings demonstrate that advocating for circular economy practices within Chemical Industrial Parks and maintaining transparency about their objectives and benefits can indeed enhance public attitudes. Notably, a Chemical Industrial Park focused on circular economy

principles received the most favorable responses, even more so than when participants were asked about a CIP situated further from their homes. *These results suggest a clear directive for the chemical industry: to integrate circular economy practices into their operations and effectively communicate these initiatives to the public.*

7. Limitations and Directions for Future Research

The primary limitations of this study derive from its relatively small sample size of 123 participants after data cleansing. Participants demographics were not entirely diverse, predominantly consisting of young adults from Germany with incomes below €20,000. The quantitative nature of the data collection needed dummy coding for regression analysis, leading to the exclusion of certain variables. The moderate explanatory power of the models, indicated by R-squared values of approximately 20% and a lenient significance threshold of $p < 0.1$ due to the sample size, suggests caution in interpreting the findings' strength. Additionally, reliance on self-reported survey data may limit the reliability of the results, pointing to the potential value of incorporating expert interviews or expanding the variables in future research.

The original research gap calls for an experimental investigation into public stigmatization towards the chemical industry. However, this study adopted an exploratory approach, analyzing survey responses. Future research could employ experimental designs, perhaps conducting long-term studies on communities residing near newly established chemical parks. Comparing these findings with other industries could also yield insightful results. Subsequent studies should aim to validate or challenge these findings, enhancing the robustness and applicability of the conclusions drawn from this exploratory research.

Bibliography

- Agentur für Forschung. 2019. *Wahrnehmung von Nachhaltigkeit*. Mannheim: Bundesrepublik Deutschland.
- Alessandrini, Michele, Pietro Celotti, Andrea Gramillano, and Marco Lilla. 2017. *The future of industry in Europe*. European Union.
- Balunde, Audra, Goda Perlaviciute, and Tina Truskauskaite-Kuneviciene. 2020. *Sustainability in Youth: Environmental Considerations in Adolescence and Their Relationship to Pro-environmental Behavior*. Front. Psychol.
- Bearth, Angela, Rita Saleh, and Michael Siegrist. 2019. *Lay-people's knowledge about toxicology and its principles in eight European Countries*. Zürich: Institution for Environmental Decisions, ETH Zürich.
- Blok, Kornelis, Jelmer Hoogzaad, Shyaam Ramkumar, Andy Ridley, Preeti Srivastav, and Irina Tan. 2016. *IMPLEMENTING CIRCULAR ECONOMY GLOBALLY MAKES PARIS TARGETS ACHIEVABLE*. Circle Economy Ecofys.
- Boele-Woelki, Katharina, Joseph S. Francisco, Ulrike Hahn, and Joachim Herz. 2018. "How We Can Rebuild Trust in Science— And Why We Must." *Angew. Chem. Int. Ed.* 13696 – 13697.
- Boyanov, Borislav. 2020. "EUROPEAN CHEMICAL INDUSTRY - CURRENT STATE AND CHALLENGES." *Economic Archive I* 57-71.
- Brudermüller, Martin. 2020. *Circular Economy at BASF*. BASF.
- Bustamente Picón, Edgar, Joan Alberich González, Yolanda Perez-Albert, and Mahdi Gheitasi. 2023. "Public Risk Perception of the Petrochemical Industry, Measured Using A Public Participation Geographic Information System: A Case Study of Camp de Tarragona (Spain)." *Environments* 1-19.
- Chen, Chao, and Genserik Reniers. 2020. "Chemical industry in China: The current status, safety problems, and pathways for future sustainable development." *Safety Science* 128.
- Chen, Ru. 2023. *China's Circular Economy Transition: Challenges and Solutions Ahead*. Copenhagen: Circular Innovation Lab.
- Chen, Ru. 2023. *China's Circular Economy Policies: Review and Reflection*. Copenhagen: Circular Innovation Hub.
- Cohen, Jacob. 1988. *Statistical Power Analysis for the Behavioral Sciences*. New York: Lawrence Erlbaum Associates.
- Deloitte. 2023. *2024 chemical industry outlook*. Deloitte Research Center for Energy & Industrials.

- Dement, Leigh M., and Lucian A. Lucia. 2022. "The Role of the Chemical Industry in Chemophobia." *BioResources* 1962-1964.
- Djerassi, Carl. 2004. "Chemical Safety in a Vulnerable World - A Manifesto." *Angew. Chem. Int. Ed.* 2330-2332.
- Duffus, John H., Monica Nordberg, and Douglas Templeton. 2007. "GLOSSARY OF TERMS USED IN TOXICOLOGY." *Pure Appl. Chem.* 1153-1344.
- Ellen MacArthur Foundation, Sun, McKinsey Center for Business and Environment. 2015. "GROWTH WITHIN: A CIRCULAR ECONOMY VISION FOR A COMPETITIVE EUROPE."
- Ellen MacArthur Foundation. 2012. "Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition."
- Entine, Jon. 2011. *Scared to Death How Chemophobia Threatens Public Health*. New York: The American Council on Science and Health.
- European Commission. 2020. *A new Circular Economy Action Plan For a cleaner and more competitive Europe*. Brussels: European Commission.
- European Commission. 2020. *REGULATION (EU) 2020/852 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088*. Brussels: European Commission.
- Ezekoye, Obi, Avinash Goyal, Laura Millroy, and Georg Winkler. 2019. *Beating the cycle: Building resilience in chemicals*. McKinsey & Company.
- forsa. 2023. *dbb Bürgerbefragung Öffentlicher Dienst 2023*. Berlin: dbb beamtenbund und tarifunion.
- Fuchs, Daniela, and André Gzásó. 2014. "Warum die öffentliche Wahrnehmung von Risiken ernst zu nehmen ist - der spezielle Fall der Nanotechnologie." *Institut für Technikfolgen-Abschätzungen der Österreichischen Akademie der Wissenschaften* 1-6.
- Geissdoerfer, Martin, Paulo Savaget, and Steve Evans. 2017. "The Cambridge Business Model Innovation Process." *Procedia Manufacturing* 8 262-269.
- Guerris, Manuel, Jordi Cuadros, Lucinio González-Sabaté, and Serrano Vanessa. 2020. "Describing the public perception of chemistry on twitter." *Chem. Educ. Res. Prac.* 989-999.
- Guo, Miaomei, and Weilun Huang. 2023. "Consumer Willingness to Recycle The Wasted Batteries of Electric Vehicles in the Era of Circular Economy." *Sustainability* 23.
- He, Guizhen, Ingrid J.C. Boas, Arthur P.J. Mol, and Yonglong Lu. 2018. "What drives public acceptance of chemical industrial park policy and project in China?" *Resources, Conservation & Recycling* 1-12.

- Hiroshima University. 2021. *Millennials and Generation Z are more sustainability-orientated -- even when it comes to money, researchers find*. ScienceDaily.
- Hodges, Paul. 2023. *Europe's chemicals market highlights move into recession, and risk of future deflation*. ICIS.
- Hong, Sheng, Yifan Jie, Xiaosong Li, and Nathan Liu. 2019. *China's chemical industry: New strategies for a new era*. McKinsey & Company.
- Huang, Lei, Jie Ban, Kai Sun, Yuting Han, Zengwei Yuan, and Jun Bi. 2013. "The influence of public perception on risk acceptance of the chemical industry and the assistance for risk communication." *Safety Science* 232-240.
- Johansen, Becca, Brais Louro, Inge Kukla, Graham Pattle, Jodie Denmark, Chris Hughes, Daniela Jeronimo, and Roque. 2021. *Economic Analysis of the Impacts of the Chemicals Strategy for Sustainability*. UK: Ricardo.
- Kaza, Silpa, Lisa C. Yao, Perinaz Bhada-Tata, and Frank Van Woerden. 2018. *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*. Urban Development. Washington, DC: World Bank.
- Kim, Jae-Hoon, and In Choi. 2019. *Choosing the Level of Significance: A Decision-theoretic Approach*. Abacus.
- Kirchherr, Julian, Denise Reike, and Marko Hekkert. 2017. "Conceptualizing the circular economy: An analysis of 114 definitions." *Resources, Conservation & Recycling* 127 (Resources, Conservation & Recycling 127) 221-232.
- Lenz, Allen, and John Lafrance. 1996. *THE CHEMICAL INDUSTRY*. New York City: U.S. Department of Commerce.
- Lieder, Michael, and Amir Rashid. 2015. "Towards circular economy implementation: a comprehensive review in context of manufacturing industry." *Journal of Cleaner Production* 36-51.
- Lin, Yi-Hsien, Tsung-Hung Lee, and and Chiu-Kuang Wang. 2021. "Influence Analysis of Sustainability Perceptions on Sense of Community and Support for Sustainable Community Development in Relocated Communities." *International Journal of Environmental Research and Public Health*.
- Liu, Xiang, Huyunting Huang, Ziang Tang, Tonglin Zhang, and Baijiang Yang. 2019. *Spars Block Regression (SBR) for Big Data with Categorical Variables*. West Lafayette: Purdue University.
- Liu, Zhuo, WeiYi Qian, and Lei Wang. 2023. *Evaluation of the Impact of Artificial Intelligence on College Students' Learning*. Tianjin: International Conference on Network, Multimedia and Information Technology (NMITCON) |.
- Martin, Phillipe. 2010. *Consumer Attitudes and Perceptions on Sustainability*. UK: The guardian.

- Mhatre, Purva, Rohit Panchal, Anju Singh, and Shyam Bibyan. 2021. "A systematic literature review on the circular economy initiatives in the European Union." *Sustainable Production and Consumption* 26 187-202.
- MirandaI, Arianna Salazar, and Matthew Claudel. 2021. *Spatial proximity matters: A study on collaboration*. PLoS ONE.
- OECD. 2021. *Trust in public institutions*. OECD iLibery.
- Palermo, Alejandra. 2018. "Preparing for an Uncertain Future." *Chemistry International* 4-6.
- Payne, Jack, and Matthew D. Jones. 2021. "The Chemical Recycling of Polyesters for a Circular Plastics Economy: Challenges and Emerging Opportunities." *ChemSusChem* 14 4041-4070.
- Preciadoa, Paulina, Tom Snijdersb, William Burkc, Håkan Stattind, and Margaret Kerrd. 2012. *Does Proximity Matter? Distance Dependence of Adolescent Friendships*. Social Networks.
- Rigall, Dr. Juan, and Dr. Georg Wolters. 2019. *EXPECTATIONS OF CUSTOMER INDUSTRIES FOR THE CHEMICAL INDUSTRY*. Willich: SANTIAGO GmbH & Co. KG.
- Rollini, Ruggero, Luigi Falciola, and Sara Tortorella. 2022. "Chemophobia: A systematic review." *Tetrahedron* 113.
- RSC. 2015. *Public Attitudes to Chemistry*. London: Royal Society of Chemistry.
- Rönisch, Ralf, and Martin Uebele. 2023. *The EU Commission's regulation plans for chemicals as part of the Green Deal: Impact on the medium- sized chemical industry*. Coroplast.
- Sahm, Wilfried. 2006. *The Chemical Industry and Public Perception*. Weinheim: WILEY-VCH Verlag GmbH & Co. KGaA.
- Schut, E., M. Crielaard, and M. Mesman. 2015. *Circular Economy in the Dutch Construction Sector: A Perspective for the Market and Government*. Rijkswaterstaat – Water, Verkeer en Leefomgeving National Institute for Public Health and the Environment (RIVM).
- Skrivanek, Smita. 2009. *The Use of Dummy Variables in Regression Analysis*. MoreSteam.
- Slovic, Paul, Baruch Fischhoff, and Sarah Lichtenstein. 1985. "Characterizing Perceived Risk." *Perilous Progress: Managing the hazard of technology* 91-125.
- Somoza-Tornos, Ana, Andres Gonzalez-Garay, Carlos Pozo, Moises Graells, Antonio Espuña, and GonzaloGuilleñ-Gosalbez*. 2020. "Realizing the Potential High Benefits of Circular Economy in the Chemical Industry: Ethylene Monomer Recovery via Polyethylene Pyrolysis." *ACS Sustainable Chem. Eng.* 3561–3572.
- Su, Zhenhua, Yanyu Ye, Jingkai He, and Waibin Huang. 2016. "Constructed Hierarchical Government Trust In China: Formation Mechanism And Political Effects." *Pacific Affairs* 771-794.

- Tsoumakas, Grigorios, and Ioannis Katakis. 2009. *Multi-Label Classification: An Overview*. Thessaloniki: International Journal of Data Warehousing and Mining (IJDWM) 3.
- Tullo, Alex. 2023. "US chemical industry will take a hit from a mild recession." *American Chemistry Council*, January 9: 25.
- VCI. 2021. *The Chemical Industry in the Public Eye: Between Devil's Work and Solutions*. Cologne: rheingold institut.
- Wirth, Karl R., and Dexter Perkins. 2005. *Knowledge Surveys: An Indispensable Course Design and Assessment Tool*.
- Xu, Ming-Xing, Shu Li, Li-Lin Rao Rao, and Zheng. 2023. "The Psychological Typhoon Eye Effect." *Sustainability*, 15, 7507.
- Zhang, Deyuan, Xuan Cui, Xinyu Fan, and Yufeng Wu. 2022. "Study on the Factors Affecting Consumers' Participation in Regulated Recycling of Waste Lead-Acid Batteries: Practice Research from China." *Sustainability*.

Appendix 1: Chemophobia

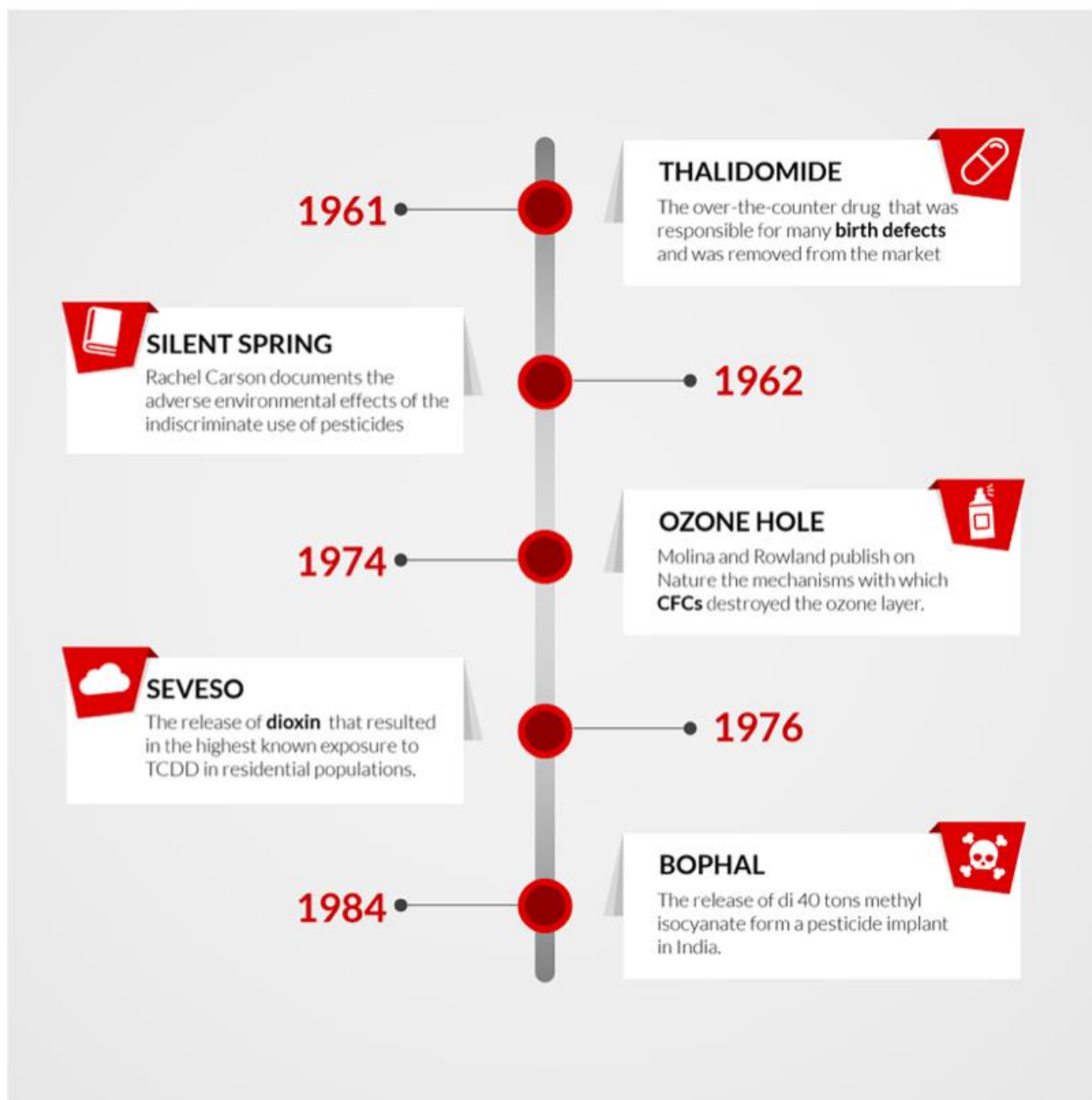


Figure A: Potential Chemophobia Timeline. Source: Ruggero Rollini, Luigi Falciola, and Sara Tortorella, "Chemophobia: A Systematic Review," *Tetrahedron* 113 (2022), p. 4.

Appendix 2: Circular Economy



Figure B: Circular Economy Effect, Source: Kornelis Blok, Jelmer Hoogzaad, Shyaam Ramkumar, Andy Ridley, Preeti Srivastav, and Irina Tan, "Implementing Circular Economy Globally Makes Paris Targets Achievable," *Circle Economy Ecofys*, 2016, p. 5

Appendix 3: Chemistry

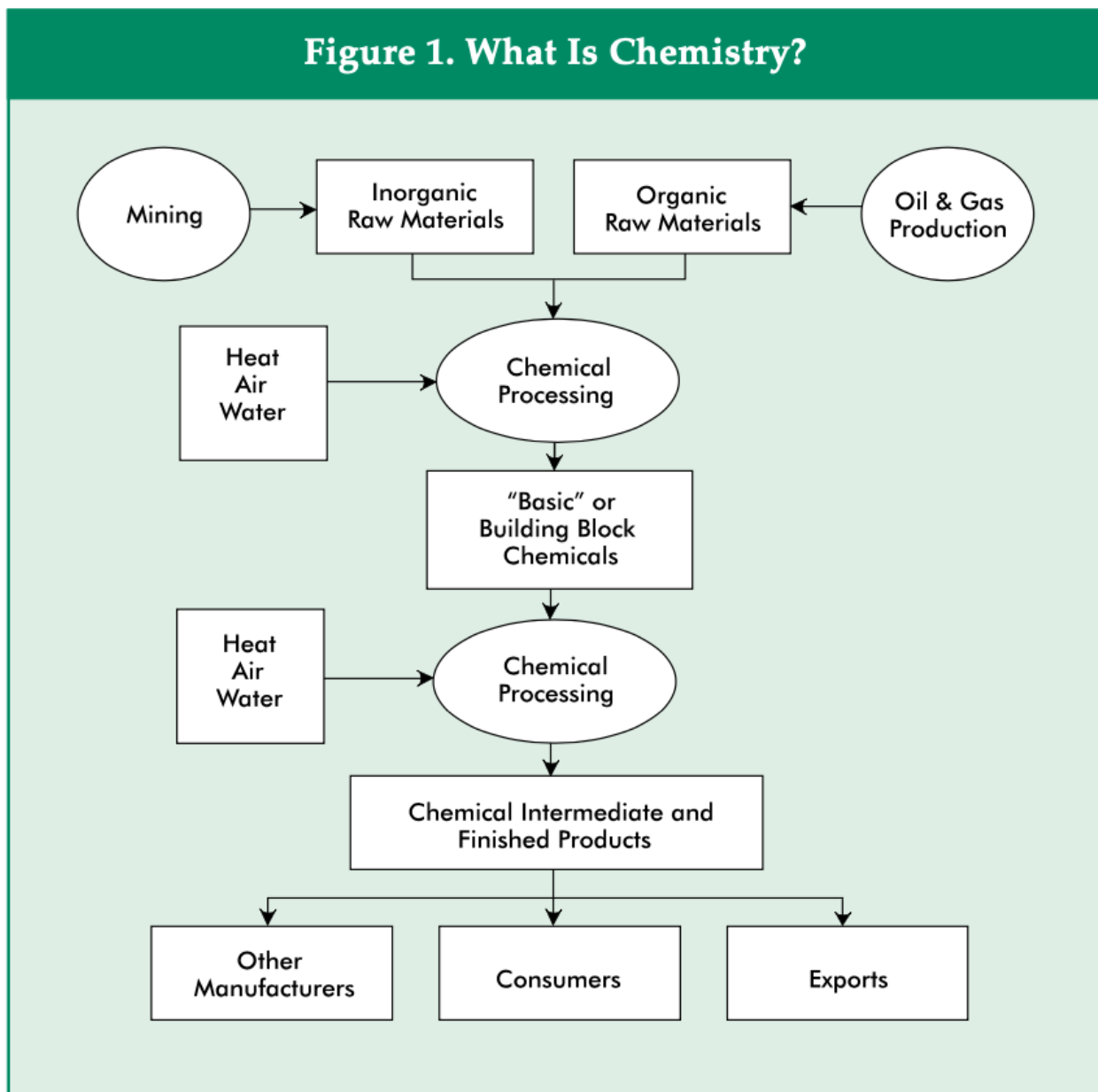


Figure C: Principles of the Chemical Industry. Source: Allen Lenz and John Lafrance, "The Chemical Industry," (New York City: U.S. Department of Commerce, 1996), p. 17.

Appendix 4: Survey Catalogue I

	in numbers	in %		in numbers	in %
What is your gender?			Which of the following statements is true about water?		
male	75	61	Water is a compound that consists of carbon dioxide (CO ₂) molecules.	6	4,9
female	46	37,4	Water is composed of two hydrogen atoms and one oxygen atom	114	92,7
diverse	1	0,8	Water primarily exists as a gas at roomtemperature	1	0,8
prefer not to say	1	0,8	Water cannot exist in a solid state.	2	1,6
What is your age range?			Which one of these practices is a key principle of the circular economy?		
<20	11	8,9	Buying new products and disposing of old ones regularly.	10	8,1
20-29	67	54,5	Using products once and then throwing them away.	0	0
30-39	7	5,7	Repairing, reusing, and recycling products instead of throwing them away.	111	90,2
40-49	6	4,9	Using as much raw material as possible to drive production.	2	1,6
50-59	24	19,5	How would you describe your interest in sustainability?		
60-69	5	4,1	Not at all interested - Sustainability has no relevance to my life or choices.	0	0
>69	3	2,4	Barely interested - I have a minimal awareness of sustainability, but it rarely influences my actions.	3	2,4
What is your highest level of education?			Somewhat interested - I recognize the importance of sustainability and occasionally consider it in my actions.	9	7,3
Less than high school	1	0,8	Neutral - I am neither actively interested nor disinterested in sustainability; I might engage with it as much as I ignore it.	15	12,2
High school graduate	38	30,9	Moderately interested - Sustainability is a factor in my daily life; I make a conscious effort to incorporate sustainable practices regularly.	57	46,3
Apprenticeship	12	9,8	Very interested - I actively seek out information on sustainability and consistently apply sustainable practices in my life.	31	25,2
Bachelor's degree	43	35,0	Extremely interested - Sustainability is a key value for me; I am dedicated to advocating for and practicing sustainability in all aspects of my life.	8	6,5
Master's degree	26	21,1	How would you rate your interest about the chemical industry?		
PhD	3	2,4	Not at all interested - I have no curiosity or concern for the chemical industry and its activities.	10	8,1
What is your gross annual income			Barely interested - I have minimal awareness of the chemical industry; it seldom crosses my mind.	34	27,6
below 20,000€	63	51,2	Somewhat interested - I have a casual interest; I might pay attention to major news or developments when they arise.	29	23,6
20,000€ - 40,000€	12	9,8	Neutral - I am neither particularly interested nor uninterested; my attention to the chemical industry is sporadic and not deliberate.	24	19,5
40,000€ - 60,000€	10	8,1	Moderately interested - I have a fair level of interest; I actively follow some news and developments within the chemical industry.	19	15,4
60,000€ - 80,000€	11	8,9	Very interested - I have a strong interest; I regularly seek out information and updates related to the chemical industry.	5	4,1
above 80,000€	27	22,0	Extremely interested - I am deeply engaged with the chemical industry; it is a significant part of my professional or personal focus, and I actively keep myself informed about all aspects of it.	2	1,6
Where are you from?			How much do you trust the media in providing accurate information about the chemical industry?		
Albania	1	0,81	Do not trust at all - I believe the media often provides misleading or incorrect information about the chemical industry.	2	1,6
Austria	2	1,63	Trust very little - I am skeptical about the media's coverage; I think it is occasionally accurate but generally unreliable.	16	13
Canada	3	2,44	Trust somewhat - I feel the media's reporting is right some of the time, but I verify information from other sources.	20	16,3
Germany	98	79,67	Neutral - I am undecided about the media's accuracy; sometimes it seems reliable, and other times it does not.	28	22,8
Italy	1	0,81	Moderately trust - I tend to trust the media's coverage, though I remain cautious and look for confirmation.	29	23,6
Luxembourg	1	0,81	Trust quite a bit - I find the media to be a reliable source for information on the chemical industry most of the time.	23	18,7
Netherlands	3	2,44	Completely trust - I fully trust the media to provide accurate and unbiased information about the chemical industry.	5	4,1
Philippines	2	1,63	What kind of media do you primarily use to form your opinion on the Chemical Industry?		
Slovakia	1	0,81	Television	96	43,6
South Africa	2	1,63	Newspaper	51	23,2
Spain	1	0,81	Instagram/Facebook/TikTok	39	17,7
Switzerland	2	1,63	X (formerly Twitter)	5	2,3
UK	1	0,81	Government Publications	13	5,9
United States	3	2,44	Friends	5	2,3
Vietnam	1	0,81	Other	11	5
Zimbabwe	1	0,81			

Table A: Survey Catalogue Socio-Demographics, Knowledge, Trust & Interest

Appendix 5: Survey Catalogue II

	in numbers	in %
Please imagine the following scenario: A large multinational chemical company decides to build a chemical industrial park within 5 km of your house, how do you feel about this?		
Very negative - I am strongly opposed and concerned about the potential risks and negative impacts on my living environment.	21	17,1
Negative - I have significant reservations and worry about the consequences for the local area and community.	34	27,6
Slightly negative - I am somewhat uneasy about it and have some doubts about the benefits versus the potential drawbacks.	32	26
Neutral - I have a balanced view, seeing potential benefits as well as risks, and am open to more information.	23	18,7
Slightly positive - I am cautiously optimistic, recognizing potential advantages such as job creation and economic growth.	7	5,7
Positive - I am supportive, believing that the industrial park could bring substantial benefits to the community.	4	3,3
Very positive - I am very enthusiastic and welcome the development, expecting significant positive impacts on the local economy and employment.	2	1,6
How do you feel if the Chemical Industrial Park will be built 100 kilometers from your house?		
Very negative - I am strongly opposed, believing it could still negatively impact the broader region	0	0
Slightly negative - I am a little uneasy about it, considering possible long-term effects on the wider area.	10	8,1
Negative - I have some concerns about its potential environmental and social impacts, even at a distance.	17	13,8
Neutral - I am indifferent as the distance minimizes direct impact on my immediate living environment.	54	43,9
Slightly positive - I am somewhat supportive, recognizing potential regional benefits without significant direct impact on me.	13	10,6
Positive - I am supportive, believing in the positive economic and employment effects it could have for the region.	22	17,9
Very positive - I am very enthusiastic, expecting substantial benefits for the wider community and minimal negative impact on my locality.	7	5,7
How do you feel if the government decides to build a chemical industrial park within five kilometers from your house?		
Very negative - I am strongly opposed and distrustful of the government's decision, fearing negative health and environmental impacts.	23	18,7
Negative - I have serious concerns about the government's ability to regulate and ensure the safety of such a development.	32	26
Slightly negative - I am somewhat skeptical and worried about potential risks, although I acknowledge there might be some oversight.	32	26
Neutral - I am ambivalent, recognizing that there could be both positive and negative outcomes from such a project.	20	16,3
Slightly positive - I am cautiously optimistic, trusting that the government has considered the potential benefits and risks.	9	7,3
Positive - I am supportive, believing that the government's involvement suggests economic and infrastructural benefits.	6	4,9
Very positive - I am very supportive and confident in the government's decision, expecting significant community and economic gains.	1	0,8
If you were provided with tools to personally check the local effects of the chemical industrial park, such as a home test kit for water quality, would this lessen your concerns about the park's risks?		
Greatly decrease my concerns - I would feel much more at ease with the ability to monitor the impact myself.	3	2,4
Significantly decrease my concerns - It would be quite reassuring to have a method to test for potential issues.	20	16,3
Moderately decrease my concerns - It would be somewhat helpful, but I would still be concerned.	33	26,8
Slightly decrease my concerns - It's a positive step, but my concerns would largely remain.	19	15,4
No change to my concerns - My level of concern would stay the same.	22	17,9
Potentially increase my concerns - The necessity to test my own water could actually make me more worried..	21	17,1
Greatly increase my concerns - The fact that I need such a kit make me think the risks are greater than I assumed.	5	4,1
Now please imagine the following scenario: The chemical industrial park is being built five kilometers next to your house to promote a large circular economy project for example by engaging in battery recycling and therefore two million kilograms of CO2-equivalents can be saved, how do you feel about the park?		
Very negative - Despite the CO2 savings, I am strongly opposed due to the close proximity and potential local risks.	4	3,3
Negative - I have concerns about the park being so close to my home, even with its environmental aims.	11	8,9
Slightly negative - I am somewhat uneasy about its location near my home, but I see the value in the CO2 savings.	23	18,7
Neutral - I am ambivalent; the environmental benefits are promising, but I am cautious about the local impact.	22	17,9
Slightly positive - I am cautiously optimistic, recognizing the environmental benefits despite some reservations about the proximity.	29	23,6
Positive - I support the initiative due to its environmental contribution, feeling that the benefits could outweigh my concerns.	27	22
Very positive - I am very supportive and excited about the environmental impact, believing the circular economy project justifies the park's location.	7	5,7
Comparing the last scenario with the first scenario, what corresponding factors changed your mind?		
Environmental benefits, such as CO2 emissions savings	78	63,4
Nothing, opinion stayed the same	20	16,3
Social benefits, particularly concerning human rights in the sourcing of raw materials	48	39
Economic benefits, including cost savings and potential economic growth	31	25,2
Transparency regarding the inner workings of the plant and its intended use.	21	17,1

Table B: Survey Catalogue Scenario Analysis

Appendix 6: Information Sources

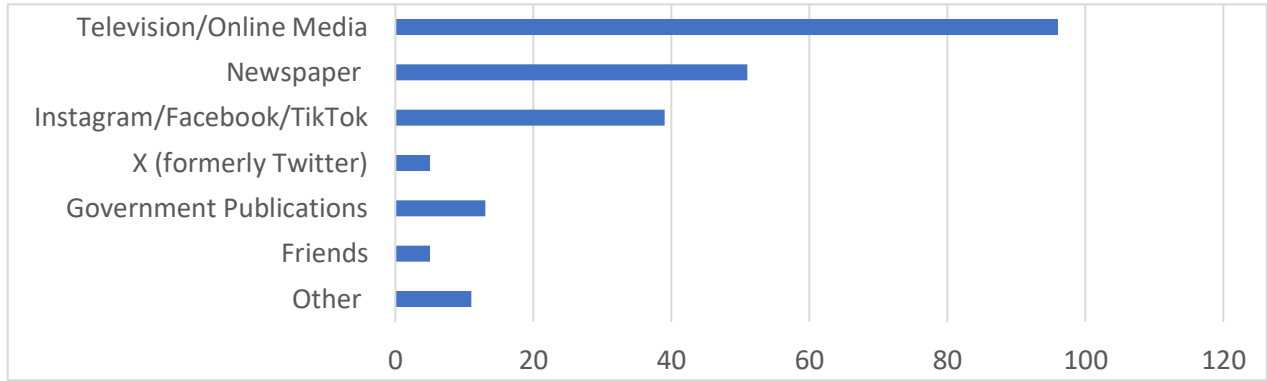


Figure D: Information Sources Chemical Industry

Appendix 7: Trust in Media

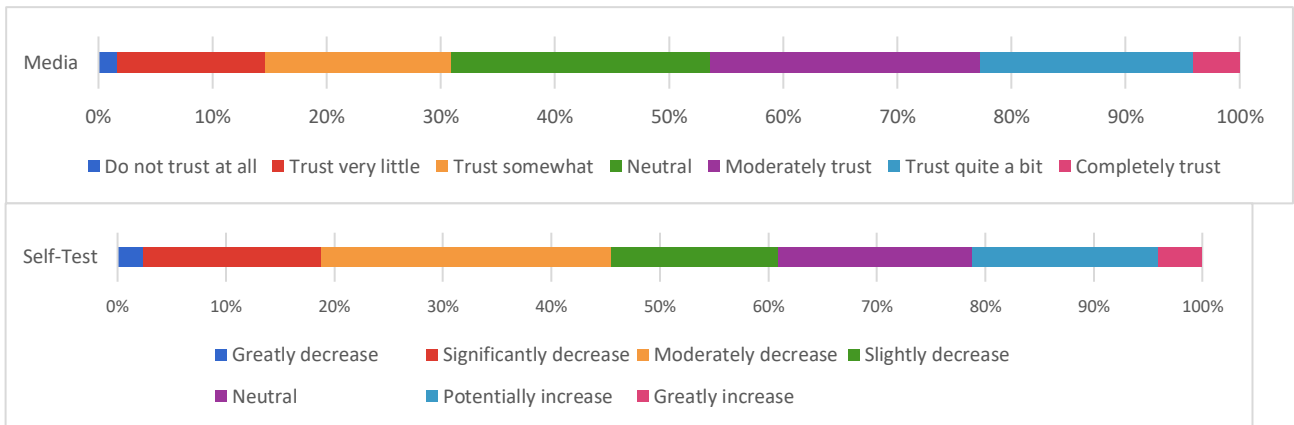


Figure E: Trust in Media and Attitudes towards Self-Test for Chemicals

Appendix 8: Attitude Change

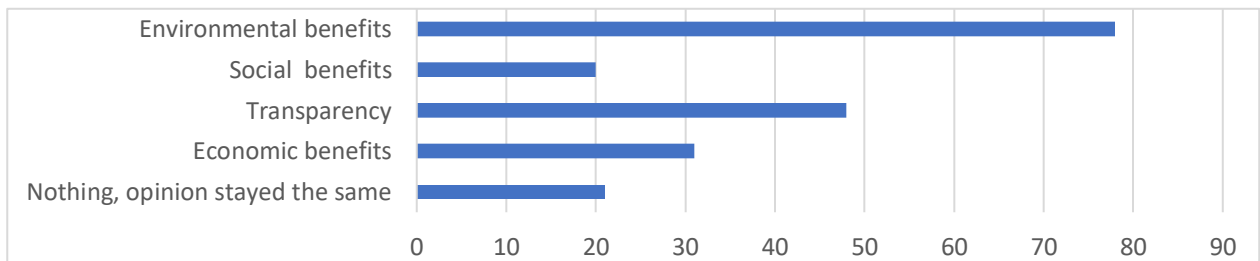


Figure F: Reasons for Attitude Change Circular Economy

Appendix 9: Correlation Results

Correlation Matrix	Are you Male?	Are you Female?	Don't you prefer to say 'I'm a parent'?	What is your age range?	What is your highest level of education?	What is your highest level of gross annual income?	Are you South European?	Are you Central European?	Are you North American?	Are you Asian?	Are you African?	Which of the following statements is true about water?	Which one of these principles is a key principle of the circular economy?	How would you rate your interest about the chemical industry?	How much do you trust the media in providing accurate information about the chemical industry?	Please imagine the following scenario: A large multinational chemical company decides to build a chemical industrial park within 5 km of your house, how do you feel about this?	How do you feel if the government decides to build a chemical industrial park within five kilometers from your house?	If you were provided with tools to personally check the local effects of the chemical industrial park, such as a home test kit for water quality, would this lessen your concerns about the park's risks?
Are you Male?	1	-0.97	-0.11	0.10	0.19	0.29	-0.09	0.00	0.03	0.13	-0.09	0.10	0.07	0.12	0.23	0.31	0.17	0.32
Are you Female?	-0.97	1	-0.07	-0.08	-0.18	-0.16	0.10	-0.03	0.01	-0.02	-0.12	-0.12	-0.03	-0.12	-0.25	-0.39	-0.22	-0.38
Don't you prefer to say 'I'm a parent'?	-0.11	-0.07	1	-0.01	-0.05	-0.11	-0.08	-0.02	-0.01	-0.01	-0.01	0.03	-0.28	0.16	-0.08	0.14	0.14	-0.06
What is your age range?	-0.07	-0.08	-0.01	1	0.05	0.40	0.54	0.04	-0.02	-0.01	0.03	0.03	-0.05	0.08	0.17	-0.08	0.19	0.20
What is your highest level of education?	-0.08	-0.05	-0.05	0.05	1	0.40	0.54	0.03	-0.14	0.08	0.20	0.10	-0.15	0.26	-0.15	-0.08	-0.09	-0.09
What is your highest level of gross annual income?	-0.18	-0.11	0.03	0.40	1	0.48	0.18	-0.18	0.01	0.09	0.02	0.06	0.15	0.20	0.01	-0.08	-0.02	0.07
Are you South European?	-0.29	-0.26	-0.08	0.54	0.48	1	0.10	-0.12	-0.08	0.01	0.24	0.02	0.19	0.27	0.00	0.00	0.00	0.01
Are you Central European?	-0.09	0.10	-0.02	0.03	0.18	0.10	1	-0.44	-0.05	-0.03	-0.03	0.06	0.07	0.02	-0.10	-0.16	-0.08	0.08
Are you North American?	0.02	-0.03	0.04	-0.14	-0.18	-0.12	-0.44	1	-0.44	-0.49	-0.34	0.03	0.06	0.02	0.33	0.27	0.19	0.21
Are you Asian?	0.00	0.01	-0.02	-0.10	0.01	-0.08	-0.44	-0.44	1	-0.05	-0.03	-0.10	-0.07	0.02	-0.16	-0.13	-0.15	-0.08
Are you African?	0.03	-0.02	-0.02	0.08	0.09	0.01	-0.05	-0.49	-0.05	1	-0.04	0.06	-0.12	-0.04	-0.10	-0.14	-0.09	-0.14
Which of the following statements is true about water?	-0.09	-0.09	-0.01	0.02	0.02	0.02	-0.03	-0.34	-0.03	-0.03	-0.03	-0.16	0.04	0.01	-0.14	-0.02	0.01	0.03
Which one of these principles is a key principle of the circular economy?	0.10	-0.11	0.03	0.15	0.15	0.19	0.06	0.03	-0.10	0.06	0.04	-0.16	-0.09	0.07	0.16	0.04	-0.14	0.06
How would you rate your interest in sustainability?	0.07	-0.03	0.03	-0.05	0.19	0.02	0.07	0.06	-0.07	-0.05	-0.13	0.05	-0.09	0.03	0.05	-0.02	0.06	-0.03
How would you rate your interest about the chemical industry?	-0.14	0.10	0.08	0.14	0.14	0.10	-0.01	0.02	0.07	-0.12	-0.01	0.04	0.09	0.37	0.04	-0.03	0.01	-0.02
How much do you trust the media in providing accurate information about the chemical industry?	0.12	-0.12	-0.08	0.26	0.20	0.27	0.02	0.03	0.02	-0.04	0.01	-0.07	0.10	0.03	0.06	0.19	0.22	0.20
Please imagine the following scenario: A large multinational chemical company decides to build a chemical industrial park within 5 km of your house, how do you feel about this?	0.23	-0.25	0.17	-0.15	0.01	0.00	-0.10	0.33	-0.16	-0.10	-0.14	-0.21	0.16	0.05	0.30	0.30	0.21	0.35
How do you feel if the Chemical Industrial Park will be built 100 kilometers from your house?	0.17	-0.22	0.19	-0.09	-0.02	0.00	-0.08	0.19	-0.15	-0.09	0.01	-0.04	-0.14	0.06	0.21	0.57	1	0.53
How do you feel if the government decides to build a chemical industrial park within five kilometers from your house?	0.32	-0.38	0.20	-0.04	-0.07	-0.01	-0.04	0.21	-0.13	-0.14	0.01	-0.14	0.06	0.20	0.35	0.89	1	0.89
If you were provided with tools to personally check the local effects of the chemical industrial park, such as a home test kit for water quality, would this lessen your concerns about the park's risks?	0.06	-0.08	0.18	-0.09	0.07	0.01	0.08	-0.06	-0.08	0.10	0.03	-0.03	0.09	-0.08	0.07	-0.13	-0.10	-0.15

Table C: Correlation Matrix Results

Appendix 10: Regression Results

Item	Attribute	Coefficient	Std. Error	Std. Coefficient	Tolerance	t-stat	p-Value	Significance
CIP 5km	Gender	0,871	0,298	0,309	0,960	2,924	0,005	***
	Trust Media	1,470	0,585	0,266	0,913	2,512	0,014	**
CIP 100km	Knowledge Chemistry	-1,116	0,570	-0,225	1,000	-1,960	0,054	*
	Trust Media	1,161	0,636	0,213	0,974	1,826	0,072	*
CIP 5km GN	Gender	0,841	0,310	0,283	0,940	2,714	0,008	***
	Trust Media	2,079	0,609	0,357	0,929	3,416	0,001	***
CIP 5km CE	Age	-1,430	0,822	-0,237	0,993	-1,741	0,086	*
	Interest Sustainability	1,759	0,918	0,241	0,984	1,916	0,059	*
	Trust Self-Test	-1,449	0,686	-0,245	0,966	-2,111	0,038	**

R-Squared CIP 5km: 0,310 CIP 100km: 0,163 CIP 5km GN: 0,328 CIP 5km CE: 0,137

* for p<0,1 ** for p<0,05 *** for p<0,01

Item	Attribute	Coefficient	Std. Error	Std. Coefficient	Tolerance	t-stat	p-Value	Significance
CIP 100km	Gender	0,253	0,323	0,091	0,956	0,781	0,437	
	Age	-0,703	0,719	-0,131	0,985	-0,978	0,331	
	Education	-0,103	0,718	-0,019	0,957	-0,144	0,886	
	Income	0,181	0,492	0,054	0,99	0,368	0,714	
	Origin	0,475	0,443	0,121	0,967	1,072	0,287	
	Knowledge Chemistry	-1,116	0,570	-0,225	1,000	-1,960	0,054	*
	Knowledge Circular Economy	0,041	0,607	0,008	0,999	0,068	0,946	
	Interest Sustainability	-0,125	0,804	-0,019	0,998	-0,155	0,877	
	Interest Chemical Industry	0,908	0,77	0,15	1	1,179	0,242	
	Trust Media	1,161	0,636	0,213	0,974	1,826	0,072	*
	Trust Self-Test	-0,131	0,601	-0,025	1	-0,218	0,828	
	(Intercept)	4,033	0,948	-	-	4,255	0	***

R-Squared CIP 100km: 0,163

* for p<0,1 ** for p<0,05 *** for p<0,01

Item	Attribute	Coefficient	Std. Error	Std. Coefficient	Tolerance	t-stat	p-Value	Significance
CIP 5km GN	Gender	0,841	0,310	0,283	0,940	2,714	0,008	***
	Age	0,397	0,689	0,069	0,993	0,577	0,566	
	Education	-0,691	0,687	-0,119	0,998	-1,005	0,318	
	Income	-0,456	0,471	-0,127	0,99	-0,969	0,335	
	Origin	0,093	0,424	0,022	0,953	0,219	0,827	
	Knowledge Chemistry	0,561	0,546	0,106	0,996	1,029	0,307	
	Knowledge Circular Economy	0,164	0,581	0,029	0,996	0,282	0,779	
	Interest Sustainability	-0,108	0,77	-0,016	1	-0,14	0,889	
	Interest Chemical Industry	1,112	0,737	0,171	0,998	1,508	0,136	
	Trust Media	2,079	0,609	0,357	0,929	3,416	0,001	***
	Trust Self-Test	-0,947	0,575	-0,169	0,997	-1,646	0,104	
	(Intercept)	0,844	0,908	-	-	0,93	0,356	

R-Squared CIP 5km GN: 0,328

* for p<0,1 ** for p<0,05 *** for p<0,01

Item	Attribute	Coefficient	Std. Error	Std. Coefficient	Tolerance	t-stat	p-Value	Significance
CIP 5km CE	Gender	0,328	0,370	0,105	0,999	0,888	0,377	
	Age	-1,43	0,822	-0,237	0,993	-1,741	0,086	*
	Education	-0,403	0,82	-0,066	0,978	-0,491	0,625	
	Income	0,086	0,562	0,023	0,921	0,153	0,879	
	Origin	0,287	0,506	0,065	0,998	0,567	0,572	
	Knowledge Chemistry	0,195	0,651	0,035	0,978	0,300	0,765	
	Knowledge Circular Economy	0,444	0,693	0,074	0,998	0,64	0,524	
	Interest Sustainability	1,759	0,918	0,241	0,984	1,916	0,059	*
	Interest Chemical Industry	-0,143	0,88	-0,021	0,989	-0,162	0,872	
	Trust Media	0,272	0,726	0,044	0,974	0,374	0,709	
	Trust Self-Test	-1,449	0,686	-0,245	0,966	-2,111	0,038	**
	(Intercept)	3,527	1,083	-	-	3,256	0,002	***

R-Squared CIP 5km CE: 0,137

* for p<0,1 ** for p<0,05 *** for p<0,01

Table D: Extended Correlation Results