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1. Introduction

1.1. Chemicals in the EU and Austria

> "Chemicals Strategy fully recognises the fundamental role of chemicals for human well-being and for the green and digital transition of European economy and society. At the same time, it acknowledges the urgent need to address the health and environmental challenges caused by the most harmful chemicals" (European Commission, 2020a)

As written in this statement from the European Chemical Strategy, industrially produced chemicals are perceived as relevant for "human well-being" and sustainable change. Simultaneously, the European Commission acknowledges their harmfulness. Regarding the EU's large chemical sector and possible effects on the planet, the EU Commission developed the Chemical Strategy as part of its Green New Deal. The strategic plan of subventions and regulations is envisioned as "the necessary first step towards Europe's zero pollution ambition" and which "strives for a toxic-free environment" (European Commission, 2020b).

This sets the geopolitical context for my study, in which I will focus on a research group that attempts to bring those two concerns of industrial and societal interests as well as "health and environmental challenges" (European Commission, 2020a) together. The laboratory research team specializes in researching and developing sustainable chemical practices for societal usage to reduce pollution and toxicity. I will elaborate on the geopolitical context of chemicals used and/or made synthetically in the following. These include chemicals used in day-to-day life, such as pharmaceuticals and washing products, or those crucial for other sectors, such as agriculture and construction (FCIO, 2022). Per- and polyfluoroalkyl substances (PFAS) and carbon monoxide (CO) are two examples of various chemicals and chemical groups that are *ecologically* problematic but that societal structures and daily life are dependent on (European Chemical Agency, 2025a; Encyclopedia Britannica, 2025; Kelkar, 2016).

PFAS are extremely persistent chemicals and can be increasingly found in "groundwater, surface water and soil." PFAS contributes to pollution and is associated with health and environmental risks. That is why the EU accounts for this group of molecules in their strategy and regulates them explicitly. The Chemical Strategy foresees "phasing out the use of Per- and polyfluoroalkyl substances (PFAS) in the EU unless their use is essential" (European Commission, 2025). Recently, one PFAS–Flufenacet–was, for instance, characterized by the European Food Security Agency (EFSA) as harmful to the human hormonal system and will consequently no longer be authorized as a pesticide (European Food Safety Authority et al., 2024; Ehnts-Gerdes & Langbehn, 2024). Conversely, these molecules are essential in the EU socioeconomic system. Flufenacet, for instance, is widely used in grain cultivation, and other

PFAS are medically used or contained in day-to-day home products (European Chemical Agency, 2025a). Connected to the zero-pollution ambition of the Green New Deal is also the newly planned strategy to promote Industrial Carbon Management. The EU envisions to "set […] a comprehensive approach to help ensure Europe meets its carbon management scale-up milestones, including actions at EU and national level" (Directorate-General for Energy, 2024). In this regard, the regulatory bodies focus on technical solutions to manage chemical pollution and greenhouse effect caused by carbon dioxide (CO_2) (Wettengel, 2024).

In line with this reduced-pollution ambition, the research group studied in this thesis aims to synthesize chemical end products with excess carbon dioxide (CO_2) as an educt, i.e. starting material. The research group's vision and practices connect to the ambivalent role of industrial and/or chemical practices. On the one hand, they are attempting to reduce chemical pollution through this "carbon managing" practice to valorize CO_2, which means utilizing it for production processes. On the other hand, their work poses a toxic risk and produces chemical waste and pollutants. In detail, the researchers work on processes that generate carbon monoxide out of CO_2, which, unlike CO_2, is toxic but highly reactive. This is a more resourceful alternative to retrieving CO gas from fossil oil and shipping it, whereby its explosivity poses additional risks (European Chemical Agency, 2025b). CO can be used for so-called carbonylation reactions of a variety of molecules (Encyclopedia Britannica, 2025; Kelkar, 2016). These CO-based chemical processes are, for instance, used in pharmaceutical production, like ibuprofen synthesis (Kelkar, 2016; Hendricks & Mott, 1992). In this way, the group attempts to navigate techno-societal structures dependent on CO (Peng et al., 2019) while avoiding the pitfalls of traditional CO retrieval and instead valorizing excess CO_2 and avoiding transportation.

The EU policies to handle harmful chemical pollution (Gargallo & Climate Bonds Initiative, 2023) are further related to local production and research and development structures in Austria since the chemical sector, with approximately 250 companies, plays a crucial role in Austria's industrial economy. This is highlighted by the umbrella association for the chemical industry (der Fachverband der Chemischen Industrie Organisation; FCIO):

> "The chemical industry belongs to the largest and most important industrial sectors in Austria." (FCIO, 2022)

Austrian governmental bodies have realized the chemical pollution and toxicity caused by these industries. Besides regulating chemical pollution, leaning on the EU strategy, they also invest in so-called Green Chemistry. It is described as "*ecological*ly oriented chemistry, which designs chemical processes and products in such a way that the use or the formation of dangerous substances is avoided or significantly reduced and that processes that are as resource-saving as possible are used" (Federal Ministry for Climate Action, Environment,

Energy, Mobility, Innovation and Technology, 2025). Thereby, actors of Green Chemistry practices are connected to less toxic chemical pollution (Marques & Machado, 2014).

The researchers of the laboratory group central to this master thesis can be seen and describe themselves as working in Green and sustainable Chemistry. The laboratory group is focused on sustainable research and development in organic chemistry concerning methodologies, possible products, and usage of excess pollutants such as CO_2 to reduce them in the environment.

The concern for *anthropogenic* chemical pollution will hence be one departure point for my research interest and case, which will be introduced shortly in the next section. *Anthropogenic*, as used here, is a term for human-related activity that impacts the planet, for instance, transportation, which is a factor of the greenhouse gas effect (Cambridge Dictionary, 2022). The term is tied to the *Anthropocene* as Scholars of different fields identify our epoch (Whitmee et al., 2015; Zalasiewicz et al., 2011). *Anthropogenic* relations to the planet are present in the history*/ies* of industries, behaviors, and technologies and are based upon colonizing, capitalistic, and oppressive racial societal structures (Yusoff, 2018). In my research, I will situate the case in this specific realm of chemical pollution, social inequities, and caring relations.

1.2. Regulation of Toxic Chemical Pollution

Toxic chemical pollution is an issue for the planetary environment and the living beings inhabiting this planet. This topic will be introduced in this chapter with a focus on its governmental regulation and will be discussed further in the State-of-the-Art chapter. Chemical Pollution is part of planetary health concerns, which center on human health effects connected to planetary damage, like chemical pollution. Pollution can be *ecological*ly damaging and/or toxic. It is related to industrial, laboratory, and/or day-to-day practices, like producing pharmaceuticals or throwing out waste that releases small, persistent chemicals. To address the issue of toxic chemical pollutants, there are regulations and practices by the Austrian government (Umweltbundesamt Österreich, 2022a) and research institutes exist to monitor toxic chemical pollution. In Austria, the Environmental Protection Agency's investigation initiatives act as a knowledge resource, gathering data from different laboratories that analyze chemical pollution and related health and environmental concerns (Umweltbundesamt Österreich, 2022b). The actions based on these efforts affect human bodies, non-human living actors, and how bodies relate chemically to their surrounding world. In this sense, different approaches are undertaken to intervene in the socio-technical dilemma of actor networks linked to chemical pollution. Further, as mentioned before, governments invest in research groups with the aim of new possibilities to change ways of doing chemical production, in which a political-economic interest exists, for instance, because of the importance of the chemical industry to Austria's economy (Marques & Machado, 2014). This can possibly affect air pollution regionally and/or in other parts of the world. From the perspective of caring for alternative production structures through research and development, I will look at a local research team that specializes in Green and sustainable chemistry.

1.3. Green and Sustainable Chemistry

In the following section, I will explain the scientific context of the research case. Green Chemistry and sustainable Chemistry are the main fields in which the research group practices. This field has been growing since the initial book “Green Chemistry: Theory and Practice” by Anastas & Warner was published in 1998. The authors developed twelve applicable principles for chemical practices (Isac-García et al., 2016), which helped spread Green Chemistry in laboratories and industries. For instance, the principle of “Make better use of available resources for the development of a chemical process” connects to the goal of the mentioned research lab to use excess CO_2 instead of fossil resources. Green and sustainable Chemistry expanded even more through conferences and the establishment of the journal “Green Chemistry” published by the Royal Society of Chemistry (Royal Society of Chemistry, 2023). These platforms enabled scientific exchange and brought a community together. However, there are differences in the understanding of Green and sustainable Chemistry. Sustainable chemistry generally describes chemistry as one that targets sustainability goals without necessarily strictly considering the twelve principles of Green Chemistry. On the other hand, the boundary between the understandings is blurred, and the interview participants of my study, who are researchers in the group, used both terms interchangeably. One participant even mentioned how they “don't like to differentiate that” (Record 2, Pos. 10). In the following, I will use “Green/sustainable” to describe the field of the mentioned research group.

1.4. Research Interest

The topic of this section will introduce my interest in this case and how I came to the research questions guiding this thesis. I wrote a term paper about planetary health during a seminar in my second year of studies. The case I focused on examined how the WHO addresses chemical pollution, specifically to mitigate cancer risk (World Health Organization, 2020). I read more literature on how chemically polluted air, injustices connected to colonialism, toxicity, and *ecological*ly damaging structures, and the well-being of living beings are intertwined. This research is also highly relevant to these topics, which are also associated with toxicity. The pollutant carbon dioxide is a central substrate of the participants' laboratory work and connects this research case to the theme of chemical pollution. CO_2, as a pollutant, impacts our temperatures due to the increased proportion in the atmosphere and the resulting greenhouse effect. On the other hand, the research group handles other toxic substances and produces waste and harmful pollutants, which they try to reduce. The tension to handle the risks and harmfulness of chemical practices while dependent on those in many aspects can be linked to the mentioned two-sidedness of the EU chemical strategy at the beginning of this introduction.

In my research, I am interested in this tension. In which ways are the researchers and participants of this study aware of pollution and toxicity? How do they attempt to find alternative and more sustainable practices and try to make a change? How do and can they care or not care for those interconnected issues of dependency on and harmfulness of chemical pollution? In the context of the laboratory group of interest in this thesis, I will pose the following research questions, which I will elaborate on more in chapter four:

How do actors practice care in the context of sustainable chemical practices in the laboratory?

- *How is sustainability understood and approached in the everyday laboratory and the discursive practices of the researchers?*
- *How do actors care for chemical pollution through their practices?*
- *For whom and what is (not) cared for?*

Considering my own human body and how I am emotionally connected to other people who are, along with me, affected by chemical pollution, I feel the obligation and desire to make a change and put effort into reducing its negative effects. I care for it. At the same time, I live in industrialized cities with an educational background, consumption behaviors, and privileges built upon politics and economics tightly bound to industrial structures responsible for harmful chemical pollution and its effects on planetary health. This feeling of responsibility, care, and tension is one of the motivators for writing this thesis.

1.5. Structure

I structure my thesis around the case study of a local chemical research group as follows: Firstly, I will introduce and discuss relevant literature from Science, Technology, and Society (STS) or related disciplines. This chapter includes perspectives on chemical pollution, toxicity, and Green/sustainable Chemistry. Secondly comes my chapter on theories and concepts. In this chapter, I will discuss the strand of Laboratory Studies, the concept of *matters of care* (Puig de la Bellacasa, 2011), connected concepts of chemical pollution, and how these theoretical considerations are connected and relevant to my study. The next chapter presents my research questions and how they build upon the chosen literature and conceptual reflection. The methodology chapter focuses on my ethnographic approach and ethical and conceptual reflections. My analysis chapter is divided into two topical areas–*matters of care* (Puig de la Bellacasa, 2011) and Green/sustainable Chemistry. In the former, I will order my analytical thoughts into the framework of *thinking-with care* relations (Puig de la Bellacasa, 2012). These can include practices that are *dissenting* towards regular laboratory ways of doing, *thinking-for* a damaged planet, or *thinking within* a community connecting different ideas and actors. The Green/sustainable Chemistry chapter analyses the data along three topical areas: goals and long-term thinking, the accompanying political aspects, and toxicity. In my discussion, I will argue how this thesis contributes to a better understanding of laboratory chemical practice in the context of a polluted planet and an industrial complex. Regarding my research questions, I will answer them conclusively through the concept of *slow activism*, discussing intimate actions, which constitute imperfect changes and a step-by-step pace with mistakes and setbacks involved (Liboiron et al., 2018). Throughout my thesis about a laboratory that strives to be more sustainable concerning chemical pollution, care is rendered visible as non-idealistic and various in its disrupting and creating qualities (Puig de la Bellacasa, 2012).

2. State of the Art

In the State of the Art (SOA), I will cover different literature strands focusing on STS and related papers that contextualize my research approach. This means collecting and introducing perspectives from the Green/sustainable Chemistry, Toxicity, and Chemical Pollution literature.

In the first part of this chapter, I will focus on chemical pollution, which is related to my case and sustainability in chemistry, as a relevant topic discussed in STS literature (Boudia et al., 2018; Liboiron et al., 2018; Murphy, 2008; Papadopoulos, 2022). Building upon this theme, I will explain different concepts–*anthropochemicals*, *chemical residues*, petrochemistry, and the *chemical regime of living*–discussed in STS literature. In the second part of the SOA, I will explore the related theme of toxicity as it is one of the main issues of chemical pollution considering planetary damage. Here, I will showcase literature on how is, was and might be dealt with hazardous substances. Thereby, I will introduce alternative approaches to *toxic politics* and *slow activism* (Liboiron et al., 2018)**.** In this context, *reparative justice* and the relations between chemicals and bodies will be discussed. In the last section of the SOA, I will bring the topics of chemical pollution and toxicity together with the Green/sustainable Chemistry field. First, I will talk about the field's emergence through STS perspectives. Then, I will go on to possible connections between Green/sustainable Chemistry and social-*ecological* activism. I will end with a conclusion and explain my research interest.

2.1. STS and Chemical Pollution

I begin this first part of my SOA by considering why chemical pollution is an important theme in my study case. Afterward, I will explain different conceptual approaches to the issues posed by this phenomenon. This includes *anthropochemicals*, *chemical residues,* and the *chemical regime of living*. I will explore the industrial field of petrochemistry to exemplify these aspects and why they matter. Finally, I will summarize why these approaches relate to my thesis.

Considering the relevance of the topic of chemical pollution to my study case, it is important to note that the lab's primary starting material for reactions is carbon dioxide (CO_2). CO_2 is a molecule common in our atmosphere and is now considered a chemical pollutant because of its heightened percentage in the atmosphere. This increase of CO_2 in the atmosphere was caused by industrial activities in the last three centuries. The heightened percentage of CO_2 and other atmospheric molecules led to the greenhouse effect (Murphy, 2008, p. 696; Center for Science Education, 2024). This *ecological* effect caused by increased amounts of pollutants means that heat generated by solar radiation is kept close to the earth's surface. This retained heat disturbs the climate balance and has led to climate change, among other things (Center for Science Education, 2024). CO_2 is, hence, part of "climate change and pollution" (Puig de la Bellacasa, 2021, p. 203). The lab tries to establish chemical production methods that use CO_2 as a building block, called valorization of CO_2. In this way, they seek ways to reduce CO_2 by using it through chemical reactions to synthesize useful molecules. The lab handles a range of other toxic chemicals that are potentially polluting the atmosphere. As a Green/sustainable laboratory, they are also sensitive to their production of chemical pollution. Considering this entanglement of chemical pollution and the laboratory's research practices, I will display STS studies about concepts related to chemical pollution. Those are the *chemical regime of living, anthropochemicals, chemical residues,* and *petrochemistry*.

2.1.1. *Anthropochemicals*

In this section, I will discuss the use of *anthropochemicals* to describe human-made chemical pollution (Papadopoulos, 2022). *Anthropochemicals* as a term are based on the concept of the *Anthropocene*, which will be introduced in the following. Afterward, I will explain in more detail the meaning of *anthropochemicals* and their relevance to my thesis. The term *ecology* will be explained and elaborated in further detail in the theories and concepts chapter.

Scholars of different fields identify the epoch we are in as the *Anthropocene* (Whitmee et al., 2015; Zalasiewicz et al., 2011). This is because human beings organized in societies impacted ecologies with industries, behaviors, technologies, the domestication of other living beings, farming and more. Central to this development were colonizing, capitalistic, and oppressive racial societal structures:

> "The Anthropocene is a project initiated and executed through anti-Blackness and inhuman subjective modes, from 1492 to the present, and it cannot have any resolution through individuated liberal modes of subjectivity and subjugation. In short, that world must end for another relation to the earth to begin." (Yusoff, 2018)

One of the main historical moments discussed at the beginning of the *Anthropocene* was in 1610, which is related to European colonialists' invasion of the American continents. Yusoff (2018) describes it as follows:

> "The invasion of Europeans in the Americas resulted in a massive genocide of the indigenous population, leading to a decline from 54 million people in the Americas in 1492 to approximately 6 million in 1650, a result of murder, enslavement, famine, and disease. This led to a massive reduction in farming and the regeneration of forests and carbon uptake or sequestration by forests, leading to an observed decline in Antarctic ice cores of CO_2 in the atmosphere. […] The origin of the Anthropocene [is tied] to the death of 50 million indigenous people (80 to 95 percent of the population), systematic violence, and chattel slavery" (Yusoff, 2018).

White supremacy and racist ideologies caused and perpetuated oppression, making the Anthropocene a non-innocent concept. Therefore, the *Anthropocene* must be seen through a critical anti-racist lens, yet not as a "white man's burden–a paternalism that is tied to a redemptive narrative of saving the world from harm on account of others while maintaining the protective thick skin of innocence" (Yusoff, 2018). It should be contextualized with different humanities, but in modern Western geological discourse, it mainly implies a white perspective, as Yusoff writes. She highlights that the *Anthropocene* is a problematic framing that naturalizes the white perspective and the associated slavery and oppression. This viewpoint renders the

dehumanization of black and Indigenous people, as well as the occupation of land and living beings, invisible. Instead, it shifts the focus towards a narrative of a 'neutral' history with a 'general humanity' that unconsciously affected ‘nature’:

> “Challenging the celebration of those histories [Anthropocene in geological literature discourse] that produce mythic accounts, underpinned by Western geologic modes of extraction and White Imperialism, is a way to challenge not just the narration of geology but where and how we might look for its marks in a decolonizing mode of geologic relation.” (Yusoff, 2018)

Yusoff suggests moving toward the understanding of a billion black Anthropocenes to emphasize the many different fractured and complex histories involved in constructing racialized humanity.

Following up on this sensibilization for racist and colonialist history, I focus on *Anthropogenic* history, which is connected to chemical practices and capitalist and colonialist human structures non-innocently attached to it. I mean by these those human structures that affect chemical production and distribution and those affected by it. Therefore, I use the term *anthropochemicals* introduced by Papadopoulos (2022). In the following, I focus on anthropogenic structures that cause harmful *ecological* effects and threats to living beings through chemical practices. These *anthropochemical* practices are imposed by capitalist and colonialist systems based on white imperialistic historical contingency. The distributed harm primarily affects groups of people and other living beings with less powerful positions in the structures of the industrial polluting *anthropocene* (Puig de la Bellacasa, 2021). However. resisting and reparative anthropochemical practices exist as well (Papadopoulos, 2022). This will be further discussed in a later section on *reparative justice* (Papadopoulos, 2021). Moreover, I will discuss the obligation and responsibility of complicit and profiting structures and the non-possibility of ‘saving the world’ from pollution (see 2.2.1. Politics of purity). However, in this section, I will introduce *anthropochemicals*.

The *anthropochemical* influence on *ecology/ies* came with far-reaching, profound, and permanent consequences for the planet. In this thesis, *ecology/ies* means deeply intertwined and related environments, living beings and non-living beings (Papadopoulos, 2021). Hence, the term *ecological* is conceptualized in this thesis as an adjective for the “interdependent interaction between multiple forms of life”, which “is collective by definition” (Puig de la Bellacasa, 2021, p. 198). Human beings are part of these *ecologies* and, therefore, are affected by anthropochemicals. Chemical entities (molecules, plastic particles, etc.) are released and/or synthesized through human chemical practices and have effects on their *ecologies,* which can be seen as an anthropogenic influence:

> "The embeddedness of human-made chemicals in modern societies and in industry is so deep that we can talk of the *anthropochemicalisation* of the social and natural world" (Papadopoulos, 2022, p. 117)

Further included are *anthropochemicals* that emerge through interactions between other *anthropochemicals* independent of human action (Boudia et al., 2018). Even though most of these chemicals are damaging (for living beings and planetary systems), life in modern societies depends on them: "Life and death is governed through *anthropochemicals*" (Papadopoulos, 2022). *Anthropochemicalisation* is a helpful concept for understanding the role of chemical practices concerning pollution in our current time, the past, and the future because it is both broad in its meaning and specific in what it is based on.

The term Capitalocene, suggested by Gill & Benatar (2020), is an alternative to the term Anthropocene, which I worked with as well in my previous mentioned term paper about planetary health during a seminar in my second year of studies. It emphasizes capitalist structural impact more generally. The Capitalocene encompasses the "planetary change" related to the historical development of certain powerful socio-economic structures (Gill & Benatar, 2020, p. 181). Considering chemical pollution, I argue that both capitalist structures as well as human behavior are relevant and embedded in each other. In contrast to *anthropologic* chemicals, *capitalocenic* chemical is not already an established term in STS literature. Therefore, I will stay with the former term. However, I wanted to acknowledge the relevance of the perspective the concept of Capitalocene gives.

2.1.2. *Chemical Residues*

Another way of talking about chemicals and their role in the Anthropocene is the term *chemical residues* (Boudia et al., 2018). I will explain this term in this section, which is of additional help in approaching my research interest in chemical pollution. *Chemical residues* are "matter out of place" and "out of time" that remain, even though they are not needed (Boudia et al., 2018, p. 171). This residual matter stems from the waste of everyday life or from pollution in industrial production processes. One of the properties of *chemical residues* is, therefore, "a negative identity" because it is "out of place"/unwanted. However, this quality of residues changes depending on time, context, and place. Another property, as described by Boudia et al., is that *chemical residues* are "slippery" (p. 169). Their materiality is hidden because of their smallness and/or through institutional ignorance due to political interests. Furthermore, *chemical residues* are irreversibly brought into the *ecology/ies* and when looking at their pervasiveness, the "past cannot be ignored" (p. 168). The artist Ariva Reed, as cited and interpreted by Puig de la Bellacasa, points out that matter is always "ancestral remnants of each other". Residues as matter are part of a complex "recirculation of the previously combined" (Puig de la Bellacasa, 2021, p. 209). This acknowledgment means responsibility for those complicit with the history of practices and habits that influence(d) the processes that caused toxic residues to be *ecological*ly damaging. It also means that waste is insufficient to explain *chemical residues*, because everything is "permanently recycled and recomposed" (Puig de la Bellacasa, 2021, p. 209). Waste implies a finality of matter, while matter is always changing and moving. This might happen sometimes in very slow ways relative to human time on earth or has long-term toxic states, but it is still recomposing. A*nthropochemicals* as residues are therefore not final waste, it is rather that they in part recompose and break down in ways that leave other toxic remnants. Secondly, these temporally and ever evolving states of matter are in their being chemically reactive with their *ecology* and hence toxic over a longer period. Thirdly, while these processes are intensified, other processes of rather harmless dismantling are slowed down due to the properties of *anthropochemicals*. In this regard, Puig de la Bellacasa highlights the role of the "white colonial-industrial complex, which developed a capacity to industrially manufacture compounds of matter designed to endure and resist breakdown" (Puig de la Bellacasa, 2021, p. 201). *Chemical residues,* which were discussed in this section, are therefore a political issue tied to historically evolved structures of technoscientific societies (Puig de la Bellacasa, 2021). In the next section I will introduce a specific anthropogenic structure and system, that evolved in the past three centuries in complicity with a "white colonial-industrial complex"–petrochemistry.

2.1.3. Petrochemistry

In this section, I will describe petrochemistry and its connection to chemical pollution, as it is as well a field of practice mentioned by the research participants. Boudia et al. (2018, p. 171) refers to the "petrochemical area" in their text about *chemical residues*. This "area" describes the current and past time in which industry, research, and "modern" life globally is based on chemical practices to synthesize products using petroleum and natural gas (Oxford English Dictionary, 2023). Using this industrial system, I will exemplify in which way capitalist and chemical structures may interplay. They relate to pollution, which was described by the earlier two concepts of *chemical residues* and *anthropochemicals.* The "petrochemical area" is one of the main factors that lead to the wide and pervasive spread of *anthropochemicals* or *chemical residues* (Murphy, 2008). Our capitalism is based on this industrialization of petrochemistry:

> "When it comes to chemicals, the capitalist mode of production is not the explanans but the explanandum." (Papadopoulos, 2022, p. 118)

Papadopoulos says here that the "capitalist mode of production" is not the reason for the *anthropochemical* pollution but is a consequence of it. The petrochemical area which is one "capitalist mode of production" that comes with products and their *chemical residues* is further leading to the "molecularization of life" (Papadopoulos, 2022, p. 118; Murphy, 2008, p. 697)–which is a phenomenon explained in the next section on the *chemical regime of living.* As said at the beginning of this SOA, it is a common "truism that synthetic chemicals have travelled to distant crevices and niches of the world", "offering us a world changed in ways both subtle and overwhelming" (Murphy, 2008, p. 696). This is true for both climate change through a "chemically recomposed planetary atmosphere to alarming future effects" and the implicit chemical pollution of not only air, but also "water, and soils" and "the very flesh of organisms, from planktons to humans" (Murphy, 2008, p. 696). As highlighted in this section, the petrochemical area is a main driver of the thorough pollution of our *ecology/ies*. In the next, I will speak about the *chemical regime of living,* an STS approach to explain the world(s) we live in built on this chemical pollution.

2.1.4. Chemical Regime of Living

Another concept relevant to my thesis is the *chemical regime of living*, as suggested by Murphy (2008), which will be discussed in this section. It acknowledges irreversible chemical relations produced by the industrial-consumption complex in our *ecology/ies*.

The author builds upon the concept of a bioeconomy leading to a "molecularization of life through biomedicine and microorganic domains" leaning on Braun and Rose (Braun, 2007 & Rose, 2007 in Murphy, 2008; Murphy, 2008, p. 697). However, Murphy's understanding of a "molecularization of life" also involves the "nonorganic molecular realm of pollution and toxicity". They list the following symptoms of the "historical emergence of a *chemical regime of living"*:

> "That it is now possible to detect multiple, individualized, and low-level accretions of synthetic chemicals in organisms can be understood as a symptom of this molecularization of life. […] molecular relations extend outside of the organic realm and create interconnections with landscapes, production, and consumption […]" (Murphy, 2008, p. 697)"

These "molecular relations" affect living beings' health independently from the local site of the molecules' production because anthropochemicals are spread pervasively in every "crevices and niches of the world" (Murphy, 2008, p. 697). However, as Ottinger's study of civic monitoring of chemical pollution has shown, epistemic and hermeneutic ignorance is included in governmental practices (Ottinger, 2022).

In these epistemic knowledge cultures, the reality is that "it is commonplace and legally acceptable for such molecular relations to escape state regulation or the spotlight of research" (Murphy, 2008, p. 698), which shapes the *chemical regime of living*. The *chemical regime of living* is characterized through–even though *anthropochemical* pollution is "detectable"–an insufficient regulation and non-responsibility of industry:

> "Our chemical regime of living is characterized by the way it allows the fumes of petrochemicals or the off-gassing of plastic commodities to be detectable but nonetheless irrelevant to corporate accountability. The costs-in lives and dollars of externalized molecular relations are distributed into proximate, peripheral, or even distant landscapes." (Murphy, 2008, p. 697-698)

"[E]xternalized molecular relations" means those materials that are not seen as direct value-producing products of the industry–*chemical residues*. Murphy frames these ignorance and denial of accountability strategies as a "regime of imperceptibility" in the *chemical regime of living* (2008, p. 698). Harmful molecular relations are measured and assessed as presumed

risks for workers and consumers - see, for instance, Reubi (2018) on tobacco - and are not seen as systematic issues by industry and institutions (Murphy, 2008). As Murphy writes (2017) in a later text on the embodiment of toxic chemical relations, focusing on risks of the "individualized body" rather than the interrelated bodies is not constructive:

> "The individualized body, as given to us by Western liberal political structures, as a container for rights, labor, risks, capital, and biological processes, will not do. The singularized body alone cannot dismantle the disturbing entanglements of knowledge-making within violent infrastructures." (Murphy, 2017, pp. 4-5)

As this decolonial critique points out, the individualization of risks feeds further into unjust harm and benefit allocation. This is problematic since the issue of *anthropochemical* pollution is not singular but is caused by and causing colonialist, racist, and unjust structures that extend bodily borders and are complexly intertwined (Murphy, 2017). Furthermore, certain parts of the land are "devalued in the larger political economy" and hence overlooked in this focus on singular bodies (Murphy, 2008, p. 698). In the concept of a *chemical regime of living*, how "the physical production and distribution of chemical harm and dispossession" is discussed makes a difference for those affected by and profiting from the chemical industry (Murphy, 2008, p. 699).

In contrast, the so-called "citizenship," where third non-governmental actors monitor pollution and speak up about connected issues, also exists and is a form of resistance. This kind of engagement describes "chemical exposure as an entry into renegotiating the terms of citizenship" (Murphy, 2008, p. 699). Actors of "biocitizenship" are politically active in an unjust *chemical regime of living* who apply "mapping and survey techniques[.]" There is, despite the hope for state regulation from "biocitizenship" actors, ignorance from the governmental side. Furthermore, as the name "biocitizenship" already implies, actors, like "illegal residents" and "communities across national borders" (Murphy, 2008, p. 699), that do not fit into citizenship structures are excluded by this definition of actors. This is not helpful because national borders and identity rather restrict it, while pollution is not:

> "Thus, nation-focused biocitizenship projects, as one dominant form of political grassroots tactic, have fostered new tactics of governing, researching, and contesting chemical exposure, while simultaneously reiterating a focus on nation that can sometimes obscure the transnational scale of political economy and leave unexamined contemporary forms of disenfranchisement." (Murphy, 2008, p. 699)

In total, monitoring practices in the *chemical regime of living* can be political, resisting, and/or risk-calculating. They can be unjust, for instance, when actors focus on some substrates and restrict them while overlooking and not monitoring other kinds of toxic pollutants.

In this section, I discussed the *chemical regime of living lenses*, which is helpful in my thesis to be attentive to chemical knowledge practices and their political, societal, and *ecological* meaning. It includes different actors like governments, affected beings, organized citizens, technoscientific monitoring devices, and communities that organize beyond individual nations. Do actors aim to decrease the production of toxic chemical relations? For whom is this done? Who is part of the monitoring and other chemical related practices? Which relations are ignored? How are the omnipresence and persistence of chemicals discussed politically and societally? The *chemical regime of living* is a lens on how actors are connected to historically emerging unjust molecularization of life. This is the complexity of the mutually intertwined relations between beings, industrial-capitalist structures, governmental actors, and *anthropochemicals*.

2.1.5. STS Concepts to Understand Chemical Pollution

In the earlier sections, I summarized different STS literature around the Anthropocene and its chemical footprint on our *ecology/ies*. I introduced STS studies describing planetary-chemical relations through the concepts of *anthropochemicals*, *chemical residues*, and the *chemical regime of living, as well as petrochemistry,* as an example of damaging systems. All these approaches explained the intertwinement between chemical practice, *anthropogenic* structures, and the pollution of *ecology/ies*, which was illustrated in the example of the petrochemical area (Boudia et al., 2018). In the next part, I will focus on the toxicity of pollution and residues. As Murphy (2008) writes on the involvement of toxicity:

> "We are in a new *chemical regime of living* in which not just genomes but the atmosphere, water, soil, nourishment, commodities, and our very bodies are apprehendable as caught in possibly toxic molecular relations." (Murphy, 2008, p. 697)

2.2. Toxicity

In this section, I will point out how toxicity can be understood and how it is inextricably joined with anthropogenic structures in our world(s). Following this, I will bring viewpoints from an STS perspective on the politics of purity and *toxic politics* (Liboiron et al., 2018). This is connected to embodiment and injustices talked about in section 2.2.2. To conclude, I will write about a possible attitude toward accepting the toxification of our world(s) while finding new ways to make reparative change possible. This leads me to my last broader topic in this SOA: Green/sustainable Chemistry as alternative practices.

Depending on context and density, chemical pollution can be harmful to living beings because of its **toxicity** in varying degrees. I want to lean my understanding of harm on what Liboiron et al. (2018, p. 333) wrote about it: "harm as that which disrupts order and existing relations", while "toxic harm also maintains systems, including those that produce inequity and sacrifice". So, it is disruptive to certain relations foundational to ecologies and living beings and can, through that effect, maintain other structures.

The individual "harm at the cellular level" by particular "polluting molecule[s] or particle[s]" is not defining toxicity sufficiently, albeit being part of it, as Liboiron et al. (2018, p. 333) argue. Only in the context of anthropogenic structures can one understand toxicity. The harmfulness of toxic entities to ecosystems depends on human action–non-human actors, like machines and microbes, are included. It contains the production of toxic chemicals, circulating them, letting them "break down," which brings new toxic *chemical residues*, eliminating them, discarding them, and more (Puig de la Bellacasa, 2021, p. 216; Liboiron et al., 2018; Sanderson, 2011). A substrate can be toxic to cells but not always to the whole body, as bodies have defense mechanisms. However, through anthropogenic actions, certain substrates are in certain amounts in certain places, which affect certain bodies differently. How one is affected depends on their protection, building resources, and power structures. For example, only human beings can install air filters, decide to eat non-pesticide-treated food, and know where to live for less contaminated air. This possibility of evading toxic chemicals is not available for all humans but depends on whether they can afford to realize this decision-making (Lane et al., 2023; Liboiron et al., 2018). This unjust and anthropogenic toxicity is a condition that is an issue now and will last for the long-term future, as some toxic chemicals will permanently affect our ecosystems (Puig de la Bellacasa, 2021; Liboiron et al., 2018).

To demonstrate the foundation of this condition in human-made structures, Liboiron et al. (2018) make a distinction between 'toxins' (e.g., venoms) and 'toxicants' (e.g., pesticides).– Toxins exist in our ecologies despite and before human actions. Toxicants are substrates existing because of anthropogenic structures. They are being distributed globally in increasing quantities and are hazardously affecting ecologies. The often unjust and anthropogenic toxicity

structures are based on toxicants. These entities are not as quickly addressed through strategies that help evade toxins, like “avoidance, clean up, antidote and care” (Liboiron et al., 2018). The toxicity issue's complexity doesn’t come without “human-related systems including industrialization, economic growth, and capitalism” (Liboiron et al., 2018).

Toxicity based on anthropogenic structures with permanent planetary effects also has features ascribed to the Anthropocene. It characterizes and is characterized by this *ecological* area (Liboiron et al., 2018).

2.2.1. Politics of Purity and Toxicity

The idea of purity might be seen as the antidote to this issue of our time and future–the state to be achieved without toxicity. In this section, I will elaborate on this concept and its criticized aspect, referring to Alexis Shotwell’s introduction in her book “Against Purity: Living Ethically in Compromised Times”. I then introduce an alternative political approach towards pollution and toxicity based on Liboiron et al. (2018).

Shotwell speaks in her introduction of the “ethos” of purity:

> “This ethos is the idea that we can access or recover a time and state before or without pollution, without impurity, before the fall from innocence, when the world at large is *truly beautiful*.” (Shotwell, 2016, p. 3)

However, Shotwell problematizes this promise of purity. Our world(s) is/are not pure, and the ideal of purity is constructed. With the “beginning of the Anthropocene,” humans strive to realize this ideal through their structures and actions that have impacted thus our *ecology/ies*. In this historical moment

> “humans [started to] worry that we have lost a natural state of purity or decide that purity is something we ought to pursue and defend” (Shotwell, 2016, p. 3).

The issue of this constructed theoretical ideal comes with “the forever-failing attempt to delineate material purity–of race, ability, sexuality, or, increasingly, illness.” (Shotwell, 2016, p. 4). This was/is motivated by societal, individual, national, and institutional actors profiting from racist, ableist, patriarchal, and medico-pharmaceutical systems, like, for instance, colonial powers establishing apartheid. Considering chemical pollution, ideals and practices dedicated to “delineate material purity”–e.g., governmental regulations that classify toxic chemicals and regulate them–are part of the *politics of purity*. This is problematic because it perpetuates a reductionist view of our obligations towards the *ecological*. It is the attempt to know and control toxicity and regenerate material purity, “delineating” what is *pure* and what is *toxic*. However, as Liboiron et al. (2018, p. 332) argue, a politics of purity through “separation, containment,

clean up and immunization" that started in the 20th century doesn't seem to have been successful in a holistic sense. *Politics of purity* have been addressing issues separately, while other problems remained and grew like the complex intertwinement of capitalistic structures, necessities of everyday life, and *anthropochemicals*. This reductionism further raises the question of selectivity on which kind of chemicals are regulated and advocated for in the politics of purity. Theriault & Kang (2021, p. 14) highlight the question of "who has the power to define 'purity' in a toxic world and with what consequences for others"? This can be connected to the question of who the decision-makers in the Anthropocene are. Whose *ecology* will be affected, and in what way will the affected *ecology* affect whom? Linking this to *anthropochemical* practices, we can think about the question posed by Papadopoulos (2021, p. 59) at the end of his essay on chemicals, *ecology*, and *reparative justice*:

> "Who has the freedom to decide what chemical substances to create and at what cost, and how is this freedom achieved?" (Papadopoulos, 2021, p. 59).

In sum, *politics of purity* hides the complexity of toxicity, unjust power relations, and our political complicity in it:

> "I argue against purism because it is one bad but common approach to devastation in all its forms. It is a common approach for anyone who attempts to meet and control a complex situation that is fundamentally outside our control. It is a bad approach because it shuts down precisely the field of possibility that might allow us to take better collective action against the destruction of the world in all its strange, delightful, impure frolic. Purism is a de- collectivizing, de- mobilizing, paradoxical politics of despair. This world deserves better." (Shotwell, 2016, pp. 8-9)

This statement by Shotwell can be applied to the hypocritical politics against pollution. It builds upon accepting the impossibility of being pure of every pollutant. In accepting toxicity as a complex condition, *toxic politics* (in contrast to a *politics of purity*) can widen the perspective by dismissing the reductionism of the unjust and unrealistic "ethos" of purity. Instead, *toxic politics* embrace "a diversity of justices, scales of agency, and relations to power to diversify concepts of what counts as politics in a permanently polluted world" (Liboiron et al., 2018, p. 333). This is due to the overall and enduring presence of toxicity, which "enables the formation of resistances, coalitions and practices" (Liboiron et al., 2018, p. 341). This includes political regulations/management, activism, industrial changes, or research and development. A *toxic politics* also needs to consider (and it already includes hiddenly) small actions, changes of habits, caring for little things, personal struggles, and non-human actions, in sum, change based on a realistic, non-idealistic, and critical perspective on humans. In this light, Liboiron et al. (2018) describe a specific form of this change as "slow activism" based on

personal ethics and not the expectations of big effects. *Slow activism* (Liboiron et al., 2018, p. 341) is built upon the acknowledgment of the role of diverse limited bodies and entangled ecologies instead of actions for "material purity" (Liboiron et al., 2018, p. 332; Shotwell, 2016).

In this section, I have explained the *politics of purity* and the issues accompanying it (Shotwell, 2016). This includes unjust power imbalances and a hypocritical stance towards toxicity and pollution. I further introduced an alternative: *toxic politics* and *slow activism* as a form thereof (Liboiron et al., 2018).

2.2.2. Embodiment and Toxicity

An important aspect to widen the perspective on toxicity and pollution is the interaction with bodies: How are they affected, and which are? This angle will be elaborated on in this section. It is essential because bodies change permanently through anthropogenic pollution, e.g. stone bodies emerge into new stones through plastic (Wang & Hou, 2023), living bodies breathe and/or metabolize *anthropochemicals*, they heal through *anthropochemicals*, they die from *anthropochemicals* (Puig de la Bellacasa, 2021; Lane et al., 2023; Liboiron et al., 2018; Papadopoulos, 2022). Speaking more generally of the chemical world, bodies are intrinsically intertwined with chemicals. Bodies consist of anthropogenic, organic, or undefinable mixed chemicals; they are part of them, and chemical practices take place in interaction with them:

> "Our bodily boundaries are penetrated and traversed by viruses, chemicals, microbes" (Shotwell, 2016, p. 7)

As Murphy (2008) writes, considering especially human bodies but also mentioning non-human beings:

> "Not only are we experiencing new forms of chemical embodiment that molecularly tie us to local and transnational economies, but so too processed food, hormonally altered meat and pesticide-dependent crops become the material sustenance of humanity's molecular recomposition. We are further altered by the pharmaceuticals imbibed at record-profit rates, which are then excreted half metabolized back into the sewer to flow back to local bodies of water, and then again redispersed to the populace en masse through the tap. In the twenty-first century, humans are chemically transformed beings." (Murphy, 2008, p. 696)

Industrial capitalism, with its productionism and consumerism, is inscribed into this aspect of bodies and toxicity. Racism and colonialism also affect unequally distributed harmfulness (Shotwell, 2016). This is linked to the environmental injustice inscribed in the

relations of bodies to *anthropochemicals*, which are based upon racist, classist, gender, and age-related, ableist factors (Lane et al., 2023; Papadopoulos, 2022). Environmental injustice builds upon how bodies are differently affected by their ability to protect themselves internally and/or externally and where they are located in time and space (Lane et al., 2023). Scholars in STS and other related fields criticize this complicity with injustices related to *anthropochemical* pollution, bringing in, e.g., queer-feminist and decolonial perspectives (Ahmann & Kenner, 2020; Puig de la Bellacasa, 2021; Liboiron et al., 2018; Papadopoulos et al., 2021; Shotwell, 2016).

> "It is to say that securing life today for some populations cannot happen without letting other populations die. […] Race, class and geographical location are vectors that navigate how environmental damage is attached only to certain places and people." (Papadopoulos, 2022, p. 117)

The richness of literature shows how bodies, the chemical pollution of our ecologies, and the history of oppression, colonialism, and inequality are deeply intertwined. It is not only regarding bodies that are affected by toxicity. This inequality comes through the mutual relationship between bodies and toxicity–taking the agency of diverse bodies and embodiments into account that enable, protect against, or otherwise influence toxicity. Critical STS literature extends the understanding of bodies and adds embodied practices to the center of attention. For instance, the practice of breathing in because it connects us through the uptake of air with its inherent (toxic) chemical relations (Ahmann & Kenner, 2020). Therefore, this affects our bodies and makes breathing a sensing air quality tool. It can be partially controlled, like holding our breath shortly when breathing in would be harmful or lethal, and it can help us to emotionally stabilize, become aware of the situation, and take the courage to action (Ahmann & Kenner, 2020). Further "bodily knowledge," e.g., smelling, feeling, or coughing to sense toxic pollution, in literature highlighted as a tool that can add to scientific laboratory-based methods of measuring pollution (Liboiron et al., 2018, p. 340). Bodies protest and resist and/or are complicit with the injustices of chemical pollution, e.g., human bodies through knowledge and political practices. Moreover, as mentioned in the section on the *chemical regime of living*, the distribution of harm and benefits through human politics is unjust:

> "toxic unevenness also describes how evidence circulates within evidentiary regimes" (Liboiron et al., 2018, p. 339)

Non-human living beings might resist or contribute together with their bodies through mutation, adaptation, incorporating or metabolizing *anthropochemicals*. However, non-humans are usually unable to use human technologies and *anthropochemical* knowledge and are less or differently protected. Regarding local knowledge practices to sense chemical

pollution differently in the EU area, one interesting resource is the Citizen Sense Project led by Professor Jennifer Gabrys (Gabrys, 2022). “Pollution sensing”, a sub-project of the Citizen Sense Project, focuses on citizens who gather data about pollution. This is not particularly related to chemical pollution; it can, e.g., also be noise, but chemical pollution constitutes a significant part. The citizens’ ways of monitoring their chemical surroundings entail an individual level of chemical relations between individual bodies, knowledge practices, and the environment. One could also argue for the project being part of the earlier mentioned “biocitizenship”, because it is connected to and funded by the EU (Murphy, 2008). In this way, it underlines the *chemical regime of living* discussed before. Human beings sense and monitor in this “molecularization of life” the hazardous pollution their bodies are affected by (Murphy, 2008, p. 696). Through their knowledge practices, they are fighting for transparency and accountability. In other ways, these citizens are complicit with the structures causing these bodily injustices through their consumption behaviors, capitalizing practices (profit of an economy based on chemical industries), or political (in)activities. Therefore, it is important not to idealize the role of embodiment and bodies in the struggle against chemical pollution and the bodies’ abilities to resist. For instance, embodied representations can also be appropriated by other political goals, as described in the text by Fiske (2018). In this study case, a symbolic hand movement - “the mano sucia” - is central, where “dipping one’s own hand into crude” oil becomes a “corporeal act” that displays toxicity and pollution (Fiske, 2018, p. 406). However, this gesture is rather publicly performed by those in power to change this harmful phenomenon possibly but not those who mostly suffer under it. It is appropriated as a movement by personalities distanced from pollution and toxicity and/or complicit with institutional structures affecting these issues. This leads to the critical question:

> “Who is granted the authority to speak, and who is spoken for, in public struggles over extraction and toxicity?” (Fiske, 2018, p. 406)

Therefore, it is important to me to consider which and how bodies are implicated in the embodiment of pollution and toxicity. Who is speaking? For whom, for which bodies? And through which embodiments?

In this section, I have discussed the different relationships between bodies, chemicals, anthropochemicals, and toxicity. This leads to a perspective on environmental injustice caused by the different power structures of these relationships. In the next part, I will continue to examine aspects of (in)justice, considering the concept of *reparative justice*.

2.2.3. *Reparative Justice*

This section will discuss *reparative justice* and its linkages to chemical practice and ecologies. Papadopoulos (2021) defines *reparative justice* through various imperatives for praxis that are based on an obligation toward the injustices that happened and are happening, which I will present in this section.

I will begin with a breakdown of the term of *reparative justice.* The second part, *justice* is a concept ontologically intertwined with *anthropochemicals* because it attends to the uneven and pervasive distribution of damage, risk, and benefits:

> "The pervasiveness of *anthropochemicals* implicates social groups and places which otherwise seem less vulnerable than those which are disproportionately affected by toxicity and pollution" (Papadopoulos, 2022, p. 118)

As Puig de la Bellacasa puts it, "industrial people in white anthropogenic cultures" are the least affected, in contrast to other living beings, who should be "opposed by *reparative justice*" (Puig de la Bellacasa, 2021).

Considering the first part of the term *reparative justice*, reparation stands for "compensation" and "repair" (Papadopoulos, 2021, p. 49). *Reparative justice* and its practice address the damage to ecologies and the beings that are part of them. Important here is the material aspect of practices to repair and compensation. *Reparative justice* is further "disanthopocentric," which implicates a de-centering on human beings and decolonial perspectives (Papadopoulos, 2021, p. 59).

In *reparative justice*, regarding *anthropochemical* pollution, "minor healings of generative chemical practice" are necessary (Papadopoulos, 2021, p. 59). *Generative* practices are described by Papadopoulos (2021) as incorporating *ecological* thoughts. *Generative chemical* practice can be academic, industrial, indigenous, across species, or individual. The focus of the *generative* approach is not to reduce chemical practices but to diversify them and the potential actors for *reparative justice* considering damaged *ecology/ies*, like citizen science projects. Further examples of *reparative justice* through generative chemistry are infrastructures of recycling and cooperation between species as in the biodegradation of *anthropochemicals* through bacteria.

In this section, I have discussed *reparative justice*, a viewpoint on the responsibilities of repair and restoration towards *ecology/ies*. I introduced *generative* chemistry, which describes chemical practices that address these responsibilities. In sum, I have emphasized the politico-social and *ecological* relevance of chemical practice within this section.

2.2.4. *Toxic Politics* and Accepting

The previous lines of argumentation highlighted that humans and their systems complicit with *anthropochemical* pollution mustn't strive for purity and a healed, non-toxic world. We arrived at "this historical moment where human-made substances are so entangled with ecologies and societies that a cleanup and an 'after' to our polluted worlds is almost unthinkable" (Papadopoulos, 2022). Chemical practice and *ecology* mutually influence and are intertwined because *anthropochemicals* depend on *ecological* context. *Ecology/ies* are dependent on, made of/with, and consist of these chemicals. Non-human and human bodies as intertwined parts of the *ecology/ies* were described in this section. Humans and other bodies are "chemically transformed beings" (Murphy, 2008). A world without toxic chemical pollution in ecologies seems to have complex intertwinements that are unrealistic to achieve (Liboiron et al., 2018; Papadopoulos, 2021). The different intertwinements of embodiments and chemical structures, shaped by complicity or resistance, vulnerability or protection, create unjust conditions. They come with discriminatory, colonialist, and racist structures. However, human beings can change ways to improve and care for our *ecology/ies* through various justice approaches (Papadopoulos, 2021; Shotwell, 2016). *Toxic politics* is about acknowledging toxicity and the obligations that come from anthropogenic planetary damage in its unequal distribution of harm and benefits (Shotwell, 2016).

Considering my research focus, I see caring practices relevant not from striving for purity but from accepting the polluted *ecology/ies* as they are historically shaped and in the present. Another aspect of my research to contextualize caring practices is the discussion of Green/sustainable Chemistry in STS studies, which will be discussed in the next section.

2.3. Green/Sustainable Chemistry

In my case, one central resource to contextualize the laboratory is literature on Green and/or sustainable Chemistry. In the introduction, I illuminated the interconnected fields of Green Chemistry and sustainable chemistry as evolving disciplines, summarizing them as Green/sustainable Chemistry. In the following section, I will explore these fields through STS perspectives and their relation to *ecological* and social activism. Before that, I will highlight the relevance of the field to my research case and how it is critically discussed within the chemical community.

In a preliminary conversation, the research leader mentioned that their lab's research is closely connected to Green Chemistry. Furthermore, Green Chemistry connects the laboratory practices I am researching with my initial interest in the issue of chemical pollution– which I focused on in the first section of this SOA. This also relates to social activism against chemical practices causing planetary damage.

Regarding the last years of the growth of Green Chemistry, Noce (2019) writes that the field is considered a promising new way to rethink the role of chemistry considering the planetary damage (Noce, 2019). However, actors acknowledge the difficulties of realization the field faces because, e.g., the implementation of twelve Green Chemistry principles does not always pay off for industries, and hence, not all possibilities are exhausted. Another challenge of implementation is that alternative methods or solvents have not always been developed to replace toxic practices. Besides the issue of balancing sustainability goals and principles of chemical practices, there is generally still criticism and hesitance that pertain to the chemical science community (Sanderson, 2011). The field is still in its beginning phase and limited in achieving its idealistic principles. Rather than changing more prominent structures of the chemical industry and academic research and development, only particular methods and solvents are slowly replaced (Sanderson, 2011). Anastas and Zimmermann, two well-known Green Chemists, highlighted that the field needs to be connected to other actors to change the impact of chemical practices in a less harmful and more sustainable way–e.g., vulnerable communities and policymakers (2018).

This section briefly explained why a critical reflection on green and sustainable chemistry is relevant to my topic and criticism within the chemical field. Following up on this, I will explore STS literature on this field in the first subsection. However, I perceived STS literature discussing Green Chemistry and/or sustainable chemistry, as relatively sparse. This might speak to its newness as a field, low frequency of lab groups for study cases, low involvement in public politics and discussions, and, foremost, technical aspects of the field. In contrast, Chemical Pollution and toxicity or local activism are much more discussed and viewed from an STS perspective. These thematical areas were spoken about earlier. In the next

subsection, I will look at Green/sustainable chemical practices embedded in social and *ecological* efforts for *reparative justice*. Here, I will discuss the rare connections between Green/sustainable Chemistry and activism against toxic pollution in STS literature and day-to-day practices and communication.

2.3.1. STS and Green Chemistry

In this section, I will discuss STS perspectives on this new field of chemistry and the connection between the field and activism.

Papadopoulos defines green Chemistry as: “attempts to create molecules that incorporate *ecological* contingency in the process of their making and the molecules themselves” (Papadopoulos, 2021, p. 42). *Ecological* contingency incorporates in this aspect “practical ways of materially constructing the worlds that humans and non-humans inhabit” (Papadopoulos, 2021, p. 42). These efforts to create different things involve an “anthropochemical approach.” First, this is because *anthropochemicals* are starting material, intermediate substrates, and subsequent products in Green/sustainable Chemistry as in any institutionalized, industrial, and modern chemical research. Secondly, to return to what I have described above, *anthropochemicals* are integral to most people's daily lives, e.g. medicine. Considering this, a *purity* approach, in contrast, is denying the irreversible pollution of the *ecology/ies*. A *generative anthropochemical* approach in Green/sustainable Chemistry can bring alternatives to oppose the current toxic and polluting *anthropochemistry*. Idealistically, the goal could be only producing benign anthropochemicals that replace toxic anthropochemicals based on polluting chemical practices, with different actors involved, like bacteria, researchers, and institutions. However, this is not a realistic scenario, at least now, given the current conditions and prospects. These attempts for “*ecological* contingency” are almost impossible to realize due to the issues I am investigating and will talk about in the discussion chapter (Papadopoulos, 2021, p. 42). Some of these issues include the fact that just replacing products and substrates can create new issues, that being non-resource-consuming in research and development is not possible, and that there is always a risk of the outcome. Puig de la Bellacasa (2021) also highlights that a green technological fix as a solution alone is too simplistic. I will, hence, illuminate limitations and possibilities to extend a reductionist approach.

In this section, I have displayed an STS understanding of the growing Green/sustainable Chemistry field because my study case is based on a laboratory group in this area. I have already pointed out the difficulties and pitfalls of this approach regarding pollution and toxicity. In the next section, I will illuminate critically the efforts of

Green/sustainable Chemistry in the last 30 years towards the discussed *ecological* issues of toxic pollution.

2.3.2. Green Chemistry, a Collective, *Ecological*, and Social Effort?

In this section, I will discuss the field of Green/sustainable Chemistry and its role in addressing the acknowledged *ecological* harmfulness of the regular chemical industry. I will argue in which way Green Chemistry can be seen as a social movement and with which limitations (Woodhouse & Breyman, 2005). I will explore the disconnect and possible commonalities between this field and other *ecological* social movements. I will then explain the proposed definition of *generative chemistry* and how it is connected to Green/sustainable Chemistry. This will allow a more open view of chemical practice outside an academically institutionalized realm.

Woodhouse & Breyman (2005) discuss Green Chemistry as a social movement, using theoretical considerations by Breyman: Green chemists are "mobilizing themselves […] to change social structures". However, the authors describe this social movement as not radical because Green Chemists do not question power structures. Instead, these scientists aim to "chang[e] the ways" of doing within the institutions (Breyman 1998, p. 209 in Woodhouse & Breyman, 2005). The authors discuss green chemists as "polite" and the movement as "elitists". "Elitists" not as a "power elite but" in the way that it is closed to scientific outsiders due to technical language and knowledge barriers (Woodhouse & Breyman, 2005, p. 209). Furthermore, Woodhouse & Breyman describe, based on their research, Green Chemical scientists as rather averse to cooperating with political and public organizations (Woodhouse & Breyman, 2005). The authors assume that scientists rather want to bring change through techno-scientific innovation. In sum, the authors see no connections between actors of green chemistry and the more radical, less elitist activism of environmentalist organizations. This might be one reason for the lack of Green Chemistry actors being mentioned in the literature about environmental activism against chemical pollution and toxicity. This disconnect could be due to non-knowledge of this field and/or its elitist institutional technoscientific and non-political character. Even though the green chemists are less radical in questioning power structures, they "are leading in directions that in some respects are more progressive than what many environmentalists are seeking" (Woodhouse & Breyman, 2005, p. 218). Overcoming this disconnect could lead to more political momentum for the Green/sustainable Chemistry field. Furthermore, environmental activists can be better informed about what is scientifically possible and what can be demanded instead of only trying to obtain bans on the most toxic substances (Woodhouse & Breyman, 2005). Since 2005, the field has grown, and some

connections with environmentalist movements have been made. One example is the U.S. organization “Coming Clean”, for which green chemistry is a field of action (Coming Clean & the Environmental Justice Health Alliance for Chemical Policy Reform, 2022; Coming Clean, 2025). Green Chemistry actors themselves also voice the need for a collective effort instead of Green Chemistry acting alone:

> “Green chemistry alone, no matter how fundamental, broad in reach and impact, is not going to be sufficient for achieving a sustainable civilization.” (Anastas & Zimmerman, 2018, p. 150)

This citation also highlights the acknowledgment of the limitedness of the field. Thinking further, Green Chemistry could be used “within citizen science,” and a connection can be built between different knowledge practices addressing the issues of a polluted world. This is partly already happening, as Papadopoulos (2022) writes:

> “from green and sustainable chemistry to the amateur science of alternative chemical practices, from traditional knowledge systems to community technoscience, chemicals increasingly become a site for experimentation with their *ecological* implications.” (Papadopoulos, 2022, p. 126)

The author coins them with *generative chemical* practices. These practices involve caring relations to *ecology/ies* while being part of toxic - not puristic - politics. *Generative Chemistry* is not exclusive to institutionalized academic and industrial research groups and human actors, e.g. “Indigenous knowledge practitioners” or “interspecies collaborations” also belong to it (Papadopoulos, 2022, p. 129). *Bioremediation*, for instance, is an “interspecies collaboration” which describes technologies of using bacteria, fungi, and plants to digest humanly produced waste (Puig de la Bellacasa, 2021). This can be industrial but also based upon communities’ efforts and involves non-human and human actors, different species, and chemical practices done in laboratories and by organisms. It is one example of “Change, even if minor, [which] emerges from creating alternative ways of existence obliged by the experience of *ecology*” (Papadopoulos, 2008, p. 129).

Green/sustainable chemists can be seen as interconnected and embedded in the realm of *generative chemistry* - obliged to the *ecological*:

> “instituted green and sustainable chemistry […] challenge established research norms and customs within chemistry itself” (Papadopoulos, 2008, p. 129)

As mentioned before, Green/sustainable Chemistry is less about radical protest than creating new ways of doing something with knowledge and institutional resources given. Papadopoulos writes that this and other alternative knowledge practices are “enough […] to

defend and maintain the life of communities facing social-*ecological* conflict and destruction". However, they do not "create sweeping societal change", at least not now (Papadopoulos, 2022, p. 129).

In rethinking chemical practices in a Green/ sustainable way, *anthropochemicals* could be one possible part of *reparative justice* (Papadopoulos, 2021):

> "What if the chemicals humans create and use can be made differently? What if we look for substances that are less harmful outside of chemical science? What if chemistry itself can transform to become aware and incorporate its *ecological* milieu in its own making?" (Papadopoulos, 2008, p. 126)

These questions leave open if and how Green/sustainable Chemistry is part of a collective effort to address *ecological* damage. It links to the concept of *slow activism* by Liboiron, which was introduced before as a form of becoming obliged in a polluted world, collectively and individually (2018). This form is part of "toxic politics within but beyond governance-via-policy, in-the-streets-activism and science-as-usual" (Liboiron et al., 2018, p. 337). This is interesting because this field is considered science-as-usual, as it is very institutional and "elitist" (Woodhouse & Breyman, 2005). Simultaneously, chemical science can be considered unusual because the practitioners explicitly consider *ecological* obligation in their knowledge practices within technoscientific research and development. Based on her engagements with soil-human relations, Puig de la Bellacasa describes how science is falsely seen in "modern capitalism" as a "promise of salvation" (2021, p. 219). However, scientific endeavors should rather feed into collective efforts (Puig de la Bellacasa, 2021). So, the question remains: in which way and to what extent do actors of Green/sustainable Chemistry care for *ecological reparative justice*? This question feeds my research interest and will be addressed within my broader main research question. This section highlighted the ambiguous situatedness of Green/sustainable Chemistry within social activism addressing pollution and toxicity. I characterized the field as both elitist and radical, academic but resisting and rethinking scientific practices; it is connected to *ecological* movements and embedded in institutions and industries that are still harmful to the planet.

2.3.3. Conclusion on Green/sustainable Chemistry in STS

In this section, I examined STS literature with links to Green/sustainable Chemistry. As my research has shown, STS literature with this focus is rare, with few exceptions (Papadopoulos, 2021, 2022; Woodhouse & Breyman, 2005). I discussed possible reasons and the alleged disconnect between the field and *ecological* social movements. Different questions emerged relevant to my research: How are Green/sustainable chemists interconnected in their practices in the realm of *generative chemical* practice in a wider understanding? How does the sustainable chemistry lab of this master thesis's study or others affect the *ecological* (Papadopoulos, 2021)?

In my investigations of these questions, I will be careful not to dismiss the impact and work of the Green/sustainable Chemistry researchers nor put them on a pedestal, blending out their limitedness. This is important because I want to gain a realistic and constructive critical perspective for my ethnographic endeavor.

2.4. Conclusion and Research Interest

In this SOA, I introduced literature on three relevant aspects of my master thesis: anthropochemical pollution, toxicity, and Green/sustainable Chemistry. All these aspects are intertwined and overlapping. Green/sustainable Chemistry is, for instance, aiming to find alternatives in this *chemical regime of living* we are in, e.g., for petrochemical practices as in this research case. However, as the concept of *chemical residues* shows, the petrochemical past will still haunt the future ecologies we are obliged to (Williams, 2023).

My literature research indicates a lack of research on critical socio-political chemical pollution in the local Austrian contexts. Furthermore, I could not yet identify more STS literature on Green Chemistry or toxic chemical pollution in the local context of Vienna, Austria, or the EU. One reason might be that the Green Chemistry field originates in U.S. American politics and academic research (Woodhouse & Breyman, 2005). Hence, I am interested in using STS-sensitizing concepts in these politico-chemical efforts in this chosen case. It is linked to toxic chemical pollution, its production, and the (chemical) relations that reemerge between several actors. With my research, I investigate the ways of caring and concern in the local context of Vienna since this is where I am a researcher. More specifically, I want to focus on the laboratory context. I am interested in the lab's role and its actors on how Green/sustainable chemical practices connected to obligations towards the *ecology/ies* are realized. I will discuss theories and sensitizing concepts in the next chapter.

3. Theory and Sensitizing Concepts

In this chapter, I will introduce theoretical concepts that are helpful as sensitizing tools for my analysis and discussion. In the first section, I will start with Laboratory Studies (Knorr Cetina, 1995) since my methodology follows this strand of case studies in STS literature. In this sense, my research follows the relations between the actors and practices in their laboratory and how knowledge is produced. A relevant lens for my approach toward laboratory studies is how practices relate to transcendent and immanent issues (Papadopoulos, 2022). Connected to this is technological determinism, a narrative for technoscientific development used by various actors, which I will investigate with a more fine-grained discussion. The next section will discuss the concept of *matters of care* (Puig de la Bellacasa, 2011). Before, I will introduce the Actor-Network theory (ANT; Latour, 1987) since the framework of *matters of care* builds upon it. I will expand on how the latter concept helps me better understand my ethnographic data regarding my research questions. Furthermore, I will explain what merging the two strands of Laboratory Studies and *matters of care* means for my research. Lastly, I will introduce the concepts of *ecology/ies*, *obligation*, and *slow activism*, which will help me reflect on my findings in the STS literature context.

3.1. Laboratory Studies in STS

In this section, I will write about one fundamental strand of Science and Technology Studies, an underlying concept for my methodology: Laboratory Studies. Karin Knorr Cetina (Knorr Cetina, 1995, p. 140) writes at the beginning of her text: “Laboratory Studies became feasible in STS when, in the 1970s, the field became more possessive of its subject and surroundings”. One “surrounding” of STS researchers was natural science laboratories. STS scholars studied social and subjective aspects of actors in the lab, where actors are usually understood as objective. Non-linear, chaotic, and negotiation processes and practices of scientific production of facts and knowledge came to light. Latour and Woolgar studied, for instance, from an anthropological perspective the power relations and arrangements of non-human and human actors needed for the production of a “fact” (Latour & Woolgar, 1979). In her work, Knorr Cetina also continues to describe the historical development of ethnographic and analytical work in Laboratory Studies. According to a constructivist view, she writes about how the social world plays an important role in the “real-time processes” of producing facts and knowledge. As revealed in different case studies of laboratory practices, the creation of facts and findings relies on negotiations or other social interactions (Knorr Cetina, 1995, p. 150). Besides the social influence, Knorr Cetina also describes three other dimensions of how “facts” are constructed through diverse factors within the lab. One is the importance of the local setting, which influences the outcome of scientific processes, and can be studied through comparing labs, for instance. The second aspect is how literary and graphical representations construct the results and are part of the processes of knowledge production, e.g., through publishing practices. Finally, laboratory work translates into the outside/social world and affects it: published results influence scientific discourse and can change technological usage; for instance, if based on these results, new medicine is developed. Laboratory studies show how construction processes happen between the laboratory and non-laboratory actors, like policymakers, industrial producers, or consumers. The overview of Laboratory Studies by Sismondo further argues for the importance of including institutional aspects of the laboratory. It further points towards cultural levels I could look at (Sismondo, 2009). How does the situatedness of the laboratory affect the view on sustainability of chemical synthesis? What are the research group's inner values, hierarchies, and goals? How did institutions affect their laboratory practices and their way toward sustainability?

3.1.1. Transcendence, Scale and Immanence

In this section, I would like to explain the conceptual difference between immanence and transcendence in modern chemistry practice based on Papadopoulos (2022). Since this is based on his fieldwork laboratory studies in Green/sustainable Chemistry, this sensibility helps me understand the practice I want to analyze and discuss in my thesis. In this context, scale is a relevant discussed concept in STS papers concerning (Green/sustainable) chemical practice. Papadopoulos conceptualizes it as:

> "not only […] measure (of volume, mass, intensity, quality or value) but also […] a specific plane on which research is undertaken and issues are resolved. […] On each and every level of scale in the life of a molecule a different *ecological* and material milieu either secures its further existence or is unable to create the right order and terminates the potential of a molecule to become widely accessible across society" (Papadopoulos, 2022, p. 121)

This means every step of making it possible to produce a molecule on another scale needs to be done in another "*ecological* and material milieu" (e.g. lab, production, first reactions, etc.). With each "*ecological* and material milieu" constituted by other actors (non-human and human), prerequisites, parameters, constraints, regulations, and more come new immanent challenges and new questions of scale: How much is needed of that substrate? How much can one produce of that product? What scale of toxicity should be applied following regulations? Hereby, the constant immanent issue of replacing substrates to adapt not at one but at every level of the research and development process is present. This is then a non-linear, "diverse and complex […] *ecology* of practices", as the relations between the actors and *ecological* milieus are intertwined (Papadopoulos, 2022, p. 122). For instance, when issues appear after the product is on the market, such as negative side-effects of a medical drug, alternative ways must be explored in the laboratory phase to change the compound and new tests in the clinical trial phase. Also, adaptation problems might occur when trying to implement and scale up a chemical practice from the laboratory milieu to the production milieu because of the new circumstances. Subsequently, at the laboratory level, new forms and conditions of chemical practices must be tested. The concept of scale is relevant to the specific case of Green/sustainable Chemistry because as the Papadopoulos (2022, p. 122) writes, scale "appears as one of the most salient and equally controversial dimensions for green and sustainable chemical practice. What kind of scale do we need? How much of it and how?" . I will discuss this controversy over scale building after introducing the two concepts of immanence and transcendence. These concepts are central to the relation between chemical practice and change towards *ecological* reparation.

3.1.1.1. Immanence

Immanence as an aspect of institutionalized chemistry incorporates the practices, thoughts, and questions that come with laboratory work. The practitioners act and (re)think within their reality. Papadopoulos describes immanence as realized through mundane empiricism in modern chemistry:

> "The empiricism of modern chemistry lies with the fact that it solves the challenges and obstacles it encounters always internally. It does not follow an external plan or grand theory but a myriad of mundane attempts to negotiate and settle uncertainties, complications, and difficulties that emerge at every specific step in the making and production of a molecule." (Papadopoulos, 2022, p. 120)

Besides mundane empiricism, there is also the notion of "radical empiricism," leaning on the concept by Deleuze and Guattari (1994). This term highlights that the practices, practitioners, and their empirical observations are inherent to each other - it is one "plane of immanence" (Papadopoulos, 2022, p. 121). It implies day-to-day questioning related to **"**inherent issues that emerge in each specific step of the invention process of a molecule all the way to its wider manufacturing" (Papadopoulos, 2022, p. 121).

3.1.1.2. Transcendence and Scalability

Transcendence describes the aspect of modern chemistry to extend the lab's boundaries. This concept stands in modern chemistry for the "drive and challenge to scale up the production of molecules" (Papadopoulos, 2022, p. 121). This aspect of realizing the product usage outside the laboratory and scaling up is also important as a thought in "each specific step" (Papadopoulos, 2022, p. 121). This can only be continuously strived for "by staying within the given constraints of this specific scale and overcoming the obstacles that emerge within it" (Papadopoulos, 2022, p. 121). Through the immanent approach in the chemical laboratory, paradoxically, the transcendent approach is necessary and vice versa for modern chemistries because:

> "if [transcendence] is not achieved within each step then transcendence collapses: the molecule is no longer produced and vanishes into the scientific archive, research papers or engineering logbooks." (Papadopoulos, 2022, p. 120)

In every research attempt that concerns scaling up a product and transcending its laboratory boundaries, immanent aspects are important, like how this chemical reaction can be stabilized in these circumstances or how a compound can be purified. Furthermore,

transcendent aspects must play a role within the immanent processes of tinkering, experimenting, and other chemical practices. The transcendent aspects of immanent laboratory practices might be: how can a certain chemical reaction be scaled up, or does it make sense to use this solution in an experiment considering its sustainability and/or costs? Overall, transcendence is imperative in chemical practice and immanence is the basis for the radical empiricism of modern chemical practice. Transcendence and immanence are interdependent and implicated in each other.

3.1.1.3. Problematization of Scale

Scaling up through the imperative of transcendence of the production of molecules has been. It is the driver of the pervasiveness of planetary damage through toxicity, chemical pollution, and derived consequential damage such as the greenhouse effect:

> "we know that scale is the engine of productionism and productionism drives growth which is a major cause of *ecological* destruction. In a shortcut, scale is linked to destruction." (Papadopoulos, 2022, p. 122)

Therefore, scale is seen as problematic. Transcendence and scaling up are responsible for a growing number of persisting chemicals and growth in the usage and distribution of chemicals, leading to toxicity in our *ecology/ies*. This is especially true regarding institutionalized and capitalistic technoscientific practices that strive towards replication and more efficient production of molecules possible. At the same time, the *ecological* milieu is considered in such upscaling-oriented structures in too simple ways:

> "For replication to happen and to create scale a process of delocalisation and the erasure of the *ecological* milieu is necessary–something that I have discussed earlier in this article in the case of modern chemistry as the imperative of transcendence. Operationalise, purify and transcend many of the actual conditions that made the experiment possible. Scale becomes a model that dominates many locales." (Papadopoulos, 2022, p. 128)

These citations and reflections on scaling up in modern chemistry through immanent practices in the lab show the reason for critique and skepticism towards scale and the related growth that comes with it. Scaling up is tied "to economic growth as the single most powerful driver of environmental destruction" (Papadopoulos, 2022, p. 123). Scale and growth are connected to "*ecological* degradation" (Papadopoulos, 2022, p. 123). In contrast, neoliberals advocate for "scale to instigate new modes of value creation that largely ignore or are opportunistic towards *ecological* damage and environmental change" (Papadopoulos, 2022, p. 123). Despite the critique and damaging effects, the scale is present–we have a specific

(large) amount of *anthropochemicals* in our atmospheres, bodies, water, and soils. The scale/no scale and growth/no growth binary thinking do not reflect the more complex reality.

First, the size of the scale does not necessarily determine the molecule's harmfulness; sometimes, small scales of *chemical residues* can be more hazardous and harder to get rid of. Further, since they are less detectable, their slow pervasive accumulation and spread lead to slow disasters (Boudia et al., 2018, p. 169).

Secondly, opposing transcendence and, therefore, scalability is, on the other hand, not possible and favorable. If, for instance, researchers do not address issues that transcend their laboratory boundaries and find ways for scaling up alternative chemical compounds and practices to scale down toxic/polluting chemical compounds, this would be ignorant towards the *ecological* damage continuously done. (Papadopoulos, 2022, p. 124).

Further, as earlier mentioned in the SOA, a world without anthropogenic substances is not thinkable, lives depend on medications, mobility, and other critical infrastructure are possible through them (e.g. batteries), *chemical residues* are distributed everywhere, etc.:

> "toxic, hazardous and primarily petrobased *anthropochemicals* are produced and used at such scale that we need a tremendous economy of scale of alternative chemicals in order to replace them" (Papadopoulos, 2022, p. 123)

As discussed in the SOA, a specific scale of alternative chemical practices is needed for *reparative justice*. "*Ecological* transition" and "any vision" (Papadopoulos, 2022, p. 123) can only be thought of with transcendence and a more fine-grained view of scale beyond a binary:

> "Scale as well as no scale, growth as well as no growth constitute a negation of the *ecological* embeddedness of *anthropochemicals* and their production, use and disposal." (Papadopoulos, 2022, p. 124)

This acceptance makes room for the following alternative questions: Which scales of which alternative substrates do we need for change? On which scale can we replace hazardous chemicals? How can we transcend ideas of sustainable chemical practices on a helpful scale? What issues of scale that we cannot ignore must be overcome immanently in every "*ecological* and material milieu" of transcending experimental practices?

3.1.1.4. Summary and Alternatives

In modern chemical practice, questions concerning transcendence, immanence, scale, and their interdependency will likely always be present. Regarding immanence, for instance, radical empirical aspects of chemical practice play a crucial role in experiments–such as how the reaction changes with different temperatures. Mundane experimenting, rethinking, and testing practices can help to achieve a stable reaction for scaling up the synthesis of a certain wanted compound. G*enerative chemistry* extends classical chemical laboratory practice, but the combination of immanent, transcendent, or scale-regarding concerns is also essential to this realm of actions. Ideas of sustainable alternatives to chemical practices must transcend the empirical realm of testing and experimenting to replace toxic chemicals and repair damage done.

Immanence ensures that in every "*ecological* and material milieu" resourcefulness and harmfulness of the circumstance are considered and tried to be avoided as best as possible. At the same time, it is important to make the necessary chemical usage on an appropriate scale possible.

Hence, scale is "crucial for the making of modern and contemporary chemistry, but the problematization of scale is even more crucial for creating alternative green and sustainable compounds" (Papadopoulos, 2022, p. 122). Papadopoulos suggests a replacement of opposing or preferencing scaling up: scaling out. By that, he means an "alternative approach to scale," which stands for seeing how different communities in various generative chemical approaches can rethink the relationship between scale and the affected boundaries. Scaling out is to question scaling up practices. This means to question the repetition of what was produced and used before. Scaling out is about experimenting with new ways of chemical practice and creating alternative forms of chemical relations that are less toxic and pollutant (Papadopoulos, 2022, p. 127). To find new practices and alternative relations, there is a need for political effort to put a diversity of scaling issues into focus, like the reduction of pollution while promoting programs to enhance biodiversity (Papadopoulos, 2022, p. 122). Besides community/local and non-academic or industrial *generative chemistry*, Green/sustainable Chemistry can be seen as another field of action needed for "scaling out" — promoting change from within institutional structures (Papadopoulos, 2022). In my analysis, I want to investigate the academic chemical practices of Green/sustainable Chemistry through the introduced STS conceptualization. I will use the concepts of *transcendence, immanence, and scaling* (Papadopoulos, 2022) as a lens for the participants' reflections on their work and visions. In the last section, I want to discuss another crucial concept for discussing my findings in the laboratory study central to this thesis: technological determinism.

3.1.2. Technological Determinism

In this section, I will introduce technological determinism, a widely used and cited view on how technological progress shapes our society. This concept is linked to the previous discussion of transcendence/immanence. The aim to transcend the boundaries of the laboratory and distribute developed technologies is a typical conclusion of the worldview of technological determinism. It will be problematized as a lens and used in my further analysis.

Wyatt (2008, p. 186) conceptualizes technological determinism as having two constituting "parts". First, "technological developments occur outside society, of social, economic, and political forces". This means that "inventors, engineers, and designers [follow] an internal, technical logic that has nothing to do with social relationships" to create "new or improved products" and practices." The "second part" of technological determinism is the belief, that "technological change causes or determines social change" (Wyatt, 2008, p. 168). To define a worldview as technological determinism, both parts must be present.

Technological determinism implies a binary of the "social" and "technological" with a unidirectional relation. The "social" does not influence the "technological", but vice versa. Some illustrative examples are the "mini-fables" (Smith & Marx, 1994, x) of the "few inventors and their inventions" per generation, which shape "human development" as "both the determinants and stepping stones" (Wyatt, 2008, p. 169). They are either seen as "unsuccessful," which means no longer relevant to societies, or "successful," which means changing societies.

> "In this way, a technological breakthrough can be claimed to have important social consequences." (Wyatt, 2008, p. 169)

In these "mini-fables" (Smith & Marx, 1994, x), only the "consequences" of technological development are highlighted (Wyatt, 2008, p. 169). The "genesis of the invention" (Smith & Marx, 1994, x) is left out in these narratives. This is typical for technological determinism based on the first constituting part of it, which was mentioned earlier that the evolution of technologies and scientific knowledge is independent of societal factors (Wyatt, 2008). This part is traditionally more focused on and criticized by STS scholars:

> "Over the past 25 years, STS has focused primarily on demonstrating how limited the first part of technological determinism is, usually by doing empirically rich historical or ethnographic studies demonstrating how deeply social the processes of technological determinism are." (Wyatt, 2008, p. 168)

This is problematized by Wyatt, too, but in connection with the second constituting part, which assumes the influence of the technological on the social. This view "leaves no space for human choice or intervention and absolves us from responsibility for the technologies we make and use" (Wyatt, 2008, p. 169). If we think in this strict sense of technological determinism, this

will lead to two different conclusions. Either that only actors who develop technologies can influence their "use and effects", which excludes other social actors such as investors or policymakers. Or further, we can "deny responsibility for the technological choices we individually and collectively make" (Wyatt, 2008, p. 169). This can be seen as problematic considering the anthropogenic *ecological* destruction that involves institutional, collective, and individual choices. Furthermore, this possibility of ignoring and denying societal influence would "ridicule those people who do challenge the pace and direction of technological change" (Wyatt, 2008, p. 169).

Besides these pitfalls of technological determinism, it is still a widely used line of thought. Therefore "we cannot ignore technological determinism" and replace it with more differentiated "accounts of the technology-society relationship" (Wyatt, 2008, p. 169). Based on the premise of laboratory studies to follow the actors, I do follow not only their practices and materialities but also their conceptualizations, which include viewpoints related to technological determinism.

This is one reason why I would like to integrate a sensibility towards technological determinism, since it is still widely spread in institutional science, underlined by this citation:

> "We also need to study explanations of people and things. Just as we treat technology seriously, we must treat technological determinism seriously" (Wyatt, 2008, p. 175)

To exemplify the presence of technological determinism in the day-to-day practice of actors, I will discuss the assumption that technology "does indeed follow an inexorable path" (Wyatt, 2008, p. 169). This can be concluded from the idea of a unidirectional relation between the "social" and the "technological," where outer factors do not influence technology. It implies that technoscientific endeavors follow a linear path towards an imaginary goal, which is to achieve. For instance, the idea of academic research, which leads to technoscientific development, would fall into a technological deterministic approach (Henwood & Marent, 2019). As Wyatt writes:

> "One of the most misleading and dangerous aspects of technological determinism is its equation of technological change with progress. From the many histories and contemporary case studies of technological change we know how messy and ambiguous the processes of developing technologies can be." (Wyatt, 2008, p. 172)

A further issue is that, as mentioned earlier, ideas of development would follow a linear trajectory, which doesn't reflect our complex, different, interrelated realities. This viewpoint of linearity blends out the uncontrollable multidirectional effects of technoscience and the involvement in interdependent, intertwined and interacting ecologies. This is, for instance, exemplified by the concepts of transcendence and immanence. The scaling processes of

products that concern immanent and transcendent aspects are non-linear and involve differently interwoven *ecological* milieus.

However, as Wyatt writes, this "is not always the actors' perspective. Some actors, some of the time, present projects as simple and straightforward."–this can be achieved through technological deterministic viewpoints since it blends out complex social-technological interactions. Similarly, "[it] is necessary for them to do so to make things happen and to justify their actions." (2008, p. 174). Here again, it is made clear that the technological deterministic approach is integral and helpful to technoscientific (knowledge) practices by actors and, thus, should not be ignored by me as an analyst.

Smith and Marx go one step further, calling for a more differentiated perspective on technological determinism (1994). The authors define a continuum of views between "hard" and "soft" technological determinism. "Hard" technological determinism assumes that "advance in technology leads to a situation of inescapable necessity" (Smith & Marx, 1994, *xii*) because it is the leading and only driver of change. This shaping deterministic power of technology can be interpreted positively as leading to societal "progress" or negatively as ending in "a totalitarian nightmare," where in both cases, technologies dictate our world(s) (Smith & Marx, 1994, *xii*). The "soft" end of the continuum, on the other hand, sees the "historical agency" in a "various and complex, social, economic, political and cultural matrix", where technological development still plays a role. It is not the "monocausal" but a "'soft', less specific, multivalent explanation" for the "presumed determinative power of technological innovation" (Smith & Marx, 1994, *xii*). This is underlined by the seemingly important role of technology in shaping society as it is.

The conceptualization of this spectrum is challenged by Wyatt, who claims that there is no "soft" pole, which is "vague" as a concept (Wyatt, 2008, p. 173). He claims that this spectrum viewpoint describes only a historical viewpoint, not a deterministic one of technology (Wyatt, 2008, p. 173). As a clearer-defined alternative to the "hard" and "soft" poles, Hughes introduces the concept of "technological momentum" as an in-between of social constructivism and technological determinism (Hughes, 1994). In the interaction of the "social" and "technological", which are, in this perspective, mutually determining each other, a "momentum" is to the further development of complex technological systems. Hence, to Hughes, "shaping is easiest before the system has required political, economic and value component", which are part of the technological momentum (Hughes, 1994, p. 112). When techno-scientific infrastructures are more established, the balance of this relation shifts towards the side of technology, as Hughes states (Hughes, 1994, p. 112). For instance, the internet is nowadays mostly present in shaping the surrounding ecologies because of its historically established omnipresence. This realization is then "useful for understanding subsequent growth and at least the appearance of autonomy" of technological systems (Wyatt, 2008, p. 174). However, as Hughes concludes,

“we must remind ourselves that technological momentum, like physical momentum, is not irresistible” (Hughes, 1994, p. 113).

This concept can be seen as implicit in one of four types of technological determinism described by Wyatt (2008, p. 175): *normative technological determinism.* Here, the acknowledgment of an excessively “complex” technological development for “social control” leads to the need for more accountability towards this development.

In the following section, I will introduce the three other types of technological determinism, as shown by Wyatt (2008). *Justificatory technological determinism* explains phenomena based on technoscientific development's “inexorable path” (Wyatt, 2008, p. 169). Institutional, political, and economic actors and other actors living and working in technoscientific societal structures are used to think in this form. Next, one can identify a *descriptive technological determinism.* Social scientists apply this to “recognize” technological determinism but rather not to “understand the reasons for it and instead focus on developing richer, more situated explanations of sociotechnical change” (Wyatt, 2008, p. 174). On the other hand, *methodological technological determinism* is used as a lens to understand the role of technoscientific influence on our world(s). It is an analytical tool. The difference between the previous two categories of technological determinism is that, first, *methodological technological determinism* is not solely descriptive but attempts to see in what ways technologies are determining. Secondly, *methodological technological determinism* implies analyzing the effects of technological development on our *ecology*, which is assumed. However, this viewpoint does not generally attribute them to social processes, as in contrast, normative technological determinism does, e.g., in the view of “physical momentum” (Hughes, 1994). *Methodological technological determinism* is present in the field of STS. When we, in STS, want to understand technology, we cannot ignore its deterministic tendencies and the belief in technological determinism itself. Acknowledging the relevance of technoscience for shaping history, society, and politics also allows us to understand the provocative statement by Wyatt:

> “that our guilty secret in STS is that really we are all technological determinists. if we were not, we would have no object of analysis” (2008, p. 175)

As these authors (Wyatt, 2008; Hughes, 1994; Smith & Marx, 1994) have criticized, there is no clear-cut singular technological determinism. Further, there is no dualism between this concept and social determinism, implied by social constructivism, which sees society as the main shaping component of our world(s) and, subsequently, technologies. This would also point toward dualism between society and technoscience, which is invalid in current anthropogenic realities. Approaches to understanding the technoscientific and social are on a continuum between these two poles, as applied in diverse articles (Matthews, 2021; Winkel,

2024). Conflicting viewpoints can exist at the same time. Different forms of technological determinism can be present depending on the relation to understanding and describing technological development in our societies (Wyatt, 2008). These different conceptualizations allow a more fine-grained view of the intertwinement of science and technology with historical and societal trajectories. Simultaneously, the reductionism of technological determinism towards the relation between the "social" and the "technological," which is used pragmatically and/or ideologically, is not ignored. Wyatt ends her text with this statement:

> "The challenges for STS remain: to understand how machines make history in concert with current generations of people; to conceptualize the dialectical relationship between the social shaping of technology and the technical shaping of society; and to treat symmetrically the categories of analysts and those of actors even if the latter includes technological determinism, anathema to so much contemporary scholarship in the humanities and social sciences." (Wyatt, 2008, p. 176)

I want to address these challenges adequately in my analytical approach. I want to take technological deterministic descriptions of my participants seriously, reflect on my own and that of literature, and be aware of different ways to express them and possible reasons.

3.1.3. Laboratory Studies and Accompanying Concepts

In this section, I have elaborated on the strand of Laboratory Studies in STS and focused on theoretical concepts that will help my analysis and discussion of my data. I introduced its origins, which started with an interest in the actors of the Laboratory and how knowledge was constructed (Knorr Cetina, 1995). Concerning modern chemical practice, I explained the concepts of scale, immanence, and transcendence and their intertwinement in research. These insights will help discuss which aspects become apparent when the researchers speak about their work and how it might impact areas other than the laboratory, such as industrial production. Thirdly, I explained the concept of technological determinism because it is a thought pattern in institutionalized science and was also apparent in my research data.

3.2. *Matters of Care* and Situatedness

In this section, I want to follow theoretical-practical questions that extend the dualism between technological and social constructivism that I analyzed in this section. What practices and relations of care play a role in incorporating technoscience, the *ecological*, and the social? For this, I will introduce the concept of *matters of care* in the following (Puig de la Bellacasa, 2011). *matters of care* is also entangled with Laboratory Studies because both provide vocabularies and lenses to understand how technoscience and society interact in research and development. For my analytical approach, I will use the terminology of different caring knowledge practices, which include *thinking-for, thinking-with,* and *dissenting-within* (Puig de la Bellacasa, 2012). In the following section, I will describe the connections between the concepts explained in the Laboratory studies section and *matters of care* and how they will help me with my research interest. Lastly, I want to introduce the care-related concepts of *ecology/ies* and *obligation* as a lens for the assemblages of actors and relations to the planetary effects regarding chemical pollution and alternative practices.

3.2.1. *Matters of Care* as a Post-ANT

Matters of care can be described as a post-Actor-Network approach (post-ANT, Michael, 2017b). As described by Micheal, Post-ANT refers to a diverse range of theoretical approaches, extending Actor-Network Theory's (ANT) possibilities (Latour, 1987). ANT is focused on actors and their knowledge/fact production practices, which are based on relations of interest and concern (Michael, 2017a). However, the post-ANT approach to *matters of care* (Puig de la Bellacasa, 2011) is more than a critical account of power relations and interest production. The concept of *matters of care* ontologically argues for using care as an extension to the focus on the construction of facts and knowledge production as in 'classical' ANT (Michael, 2017b). In contrast, care emphasizes nurturing and maintaining life, livable structures, and *ecology/ies* through different practices and relations, possibly linked to knowledge/fact production (Puig de la Bellacasa, 2011). Those *caring* practices and relations are built upon *ethico-political* concerns, which address power inequalities, marginalization of interests, and life-threatening structures. *Ethico-political* means that these relations have aspects of political interests and power relations but are also shaped by values, thoughts, affects, and emotions. Both (ethical and political) are inextricably intertwined, as this statement by Michael (2017b) summarizes:

> "to pursue 'matters of care' is to affect and be affected by the thing at stake within a particular controversy or debate" (p. 131)

Actors are involved in “debates” with their political interests but also “affect” and are “affected” through their caring relations (Michael, 2017b, p. 131). It is not simply about adding another layer of emotions and values. In the case of *caring* based on *ethico-political* concerns, being critical is not a practice of distancing but connecting with “the thing at stake” in new ways and making space to care for what was previously unseen and undervalued (Michael, 2017b).

This understanding of care defines relations while care is also defined through these relations. Care relations are not linear and do not consist only of abstract interests. They involve the embodiment of actors, their practices, and how they are positioned towards the things and ecologies they are acting on. These relations include but do not exclusively consist of power relations, agencies, and interests of the actors. Care rather highlights embodied and complex relations that involve living beings.

Considering chemical relations, living beings are affected by and affect the dynamically changing assemblages of chemical practices surrounding (toxic) pollution. Assemblage refers to the relational understanding of ‘classical’ ANT. As Müller & Schurr (2016) write:

> “At their most basic, assemblages could thus be thought of as a collection of relations between heterogeneous entities to work together for some time.” (p. 219)

Extending this definition, the authors write that there is a “vital, affective quality” to assemblages–they are continuously in the stage of becoming but never fully stable (Müller & Schurr, 2016, p. 219). Assemblage as a concept is more suitable for *matters of care* to understand the connections between actors than the concept of network in ANT because assemblage implies complex, non-linear *caring* interrelations and interdependencies. Puig de la Bellacasa presented this conceptual approach in her text “matters of care in Technoscience: Assembling Neglected Things.” (2011). The concept of assemblages emphasizes the fluctuations, insecurities, eventfulness, unexpectedness, and flow in the relations of actors. Further, in this proposal, *matters of care* is chosen as a lens on relations because it shows how people (me included) might care through their doings for their *ecology* in an ever-changing and flexible way. In this sense, I am drawn to the statement of Puig de la Bellacasa: “nothing holds together in a livable way without caring relationships” (2011, p. 100). Hence, actors need to and already care for how their consumption, knowledge, and work practices are involved in producing (toxic) chemical pollution because it threatens life. This necessary reflection on our chemical impact connects to the text by Murphy on chemical relations and their implications for the embodiment of living beings (Murphy, 2017).

Moreover, my study transforms the topic of sustainable chemistry actors addressing chemical pollution issues into a *Matter of Care*. It is part and effect of a “sociotechnical assemblage”, which involves intertwined technoscientific and social entities, like chemical practices, industry, laboratories, consumers, etc. Historically, there has been a “neglect of

caring relationalities" in this assemblage regarding its damaging effects on *ecology/ies* and living beings (Puig de la Bellacasa, 2011, p. 94).

It is therefore important to highlight again that my engagement with the field makes the topic into a *Matter of Care* in a specific way, and I am not an impartial observer of this assemblage and the connected already existing concerns:

> "In that sense, this notion of 'matters of care' stands for a version of 'critical' STS that goes further than assembling existing concerns, yet resists the pitfalls identified by Latour: ready-made explanations, obsessions with power, and the imposition of moral or epistemological norms" (Puig de la Bellacasa, 2011, p. 100)

That means I use an understanding of care, that is not morally idealized. Rather, it accounts for a complex relationship between living beings that involves but extends the dimensions of interest, agency, and concern. In sum, the actors, their relations, and their care practices together enact a *politico-ethical* assemblage I want to analyze with this thesis. As is highlighted in the following statement, this approach is a tool with which I intervene:

> "As a transformative ethos, caring is a living technology with vital material implications for human and non-human worlds." (Puig de la Bellacasa, 2011, p. 100)

In the next section, I will differentiate the various forms of practices within *matters of care* (Puig de la Bellacasa, 2011).

3.2.2. Knowledge Practices Within Caring Relations

Puig de la Bellacasa sketches a terminology of three different ways of thinking with care in her text "'Nothing comes without its world': thinking with care" (Puig de la Bellacasa, 2012). I will explain this framework in the following paragraphs as I use it in my analysis. These three areas, overlapping and might not be sufficient to cover every caring relation in knowledge practices, are *thinking-for, dissenting-within,* and *thinking-with*.

Thinking-for describes practices that involve caring and thinking for others. These practices rely on relations between actors and the constructed *other(s)* (this can be a person or society but also constructed entities such as the future). However, the conceptual category *thinking-for* sensitizes the construction of otherness carefully by reflecting on one's involvement and limitations and the agency of those *others* (animals, ecologies) one wants to speak for. *Thinking-for* must be accompanied by acknowledging the risks of "appointing ourselves as spokespersons for the marginalized" (Puig de la Bellacasa, 2012, p. 208). Otherwise, this *caring* relationship only perpetuates unjust power. This sensitivity towards caring-for relations can be applied to the knowledge practices of the actors investigated in this proposed study and myself as a researcher. It is about ways of caring for *ecology* and its effects on living beings while resisting the construction of reductionist o*therness*.

As a researcher, I must also be attentive to how caring for something implies detachment from other important things. Regarding chemical practices caring for planetary impacts, the question might be: What chemical pollutants cannot be cared for in the same way as others? What chemical products are essential for care practices for specific groups of people while being sources of toxic *chemical residues*? In this light, the area of practices that fall into *dissenting-within* emphasizes the heterogeneity of caring relations and their implications for the world in contrast to an idealized image of them. Care is multi-layered and "non-innocent" (Puig de la Bellacasa, 2011, p. 98). Not everything can be cared for; there will be "cut[s]" of relations that, however, will "foster relationships" and let other caring relations emerge and sustain (Puig de la Bellacasa, 2012, p. 204):

> "Where there is relation there has to be care, but our cares also perform disconnection" (Puig de la Bellacasa, 2012, p. 204)

As an actor situated and embedded in a network, one can simultaneously dissent through critical (self-)reflection, humor, and attempts to change *within* the encompassing caring relations. Considering my research, as an analyst of my data or my participants in Green/sustainable Chemistry, I can care through knowledge practice while *dissenting* with relations and practices *within* our assemblages.

Lastly, *thinking-with* emphasizes the implications of *ethico*-political caring practices (Puig de la Bellacasa, 2012). Those practices are not based on *thinking-for* somebody/something but *with* yourself, other beings, and *within ecology/ies*. This area of care builds upon Donna Haraway's conception of situated knowledge, which is based on feminist critical theory. Situatedness emphasizes the dependence of knowledge on how and in which context it is produced. Actors and their practices of knowledge production are positioned within a thick, interconnected, ever-evolving world. The bodies involved, location, relations, and positionalities influence what is taken up through senses (hearing, seeing) and tools/technologies (ears, microscope). Through their embodiment and interrelatedness, this situatedness of actors and practices further affects the uptake, processing, and construction of perspectives and bits of knowledge (Haraway, 1988). In my study, the actors are situated in a thick assemblage of multiple relations that affect and allow for their knowledge production, like cooperating with their technological tools or community building. I focus on how these relations are affected by and affect *care.* In my research, looking at how caring practices are situated within these relationships is crucial. The category of *thinking-with* shines a light on these knowledge practices based on such caring relations situated within assemblages.

The previously explained terminology by Puig de la Bellacasa (2012) helps differentiate the concept of *matters of care* dependent on actors, their context (e.g., spatial, temporal), and their *situated knowledge* (Haraway, 1988). Hence, analyzing caring relations involves the responsibility to be simultaneously interwoven within the investigated case and able to reflect on it critically.

3.3. *Matters of Care* and Laboratory Studies

I want to connect *matters of care* with Laboratory Studies because the former concepts are sensitive to the complex situatedness of actors within the laboratory. The STS strand of Laboratory studies gives the fundament for the methodology and data to be analyzed. In the following, I will highlight the connection between these two sensitizing viewpoints in my research on the example of the concepts of immanence and transcendence.

Immanence and transcendence, as intertwined focus points of modern chemical practice, are also tied to care practices. How are they involved with caring within the lab?

This can concern the immanent questions of experimental processes, their sustainability, or their accuracy. How do they determine that things work, how many resources are used, and how many toxic *chemical residues* are produced? These empirical reflections are also tightly connected to transcendence in the caring aspect: How does this immanent caring affect the *ecologies* extending the boundaries of the laboratory? For instance, in which way are their doings contributing to *dissenting* from pollution, and how do their caring for *ecologies* and the future motivate them in their laboratory practice and reflections?

Immanence might also be the plane of reflecting on their mutual caring relations. How do social relationships play a role? How are they affecting them? Are they affected by their interactions immediately?

Considering transcendence, developing alternative reparative chemical practices is necessary for a realistic change that involves the idea of *ecology/ies* and *care* (Papadopoulos, 2021):

> "[…] how could we safely assist the breakdown of compounds created with technoscientific processes and mixes without some scientific assistance? How can we locally address the global challenge of intoxicated soils without precise knowledge of the toxics underground?" (Puig de la Bellacasa, 2021, p. 219)

In summary, this section has shown how the concepts of transcendence and immanence derived from the strand of Laboratory Studies are well complemented by aspects of *matters of care.* How do Green/sustainable Chemistry actors *care* for immanent questions of practice to develop and maintain crucial processes in the laboratory? How do they *care* for transcendent aspects, such as pollution transcending laboratory boundaries or published results that lead to changed practices in the industry? Conclusively, the connection of different concepts led me to questions that re-interpret my more generalized main research question of how actors practice care. Before I conclude the theories and concept chapter, I will explain on a theoretical level the concepts of *ecologies* and *obligations* relevant to my merged interest in care, Laboratory practice, and Green/sustainable Chemistry aspects.

3.4. Chemistry, Care and STS

In STS, scholars deconstruct technoscientific academic and industrial understandings and practices in chemistry but also try to rethink these understandings and practices through feminist and decolonial perspectives (Liboiron et al., 2018). This part of the theories and concepts chapter brings the *ecological* and chemical aspects in connection with the conceptualization of *matters of care,* which is based on feminist theories (Puig de la Bellacasa, 2011). Critical accounts of colonialist and capitalist structures will be important to understanding the concept of *obligation* and *ecology/ies,* which I will introduce in this section (Papadopoulos et al., 2021). The following conceptual explanations will be a basis for my observations in the chemical lab, my conversations with the participants on human and non-human actors, and broader conclusions based on this data.

In the following two sections, I will depict the concepts of *obligation* and *ecology/ies* important to understand the foundation of caring for chemical practices, pollution, and its planetary damaging effect. First, I will speak about *ecology/ies* to give a broader understanding of what is affected and what we are obliged to. In the last section, I will then elaborate more on the concept of *obligation* and responsibility before I move on to a summary of my theory chapter.

3.4.1. *Ecology/ies*

In this section, I will introduce the concept of *ecology/ies*, which is used in STS studies around chemical pollution and toxicity. The intertwinement of "worldly connections between different beings and environments" makes up what is understood ontologically as *ecological* (Papadopoulos, 2021, p. 37). It, therefore, extends the idea of environmental damage, which is rather harm understood as caused by human beings but not involving them. *Environmental* alone creates distance between the "environment" and the "human world". In contrast, *ecological* highlights the interdependent connections between all living and non-living beings.

Ecology/ies implicate various meanings sorted in registers that are partially in conflict or at least different but, in their entirety, constitute a *generalized ecology*. Papadopoulos describes six registers, showing the variety of meanings (Papadopoulos, 2022, pp. 124f). For instance, the ontic register of "relations and becomings among beings doing life together" is helpful to understanding literature and the meaning of modern chemical practice for the *ecological.* However, it is not helpful to concentrate on sole registers instead of thinking about them together. The isolation and emphasis of singular registers, like the economic *ecology/ies* in current discourses, leads to the possibility of ignorance towards destroying *ecology/ies* in *general.* Focusing on other registers alone - like the "lived register of the everyday experience

of rootedness and belonging" - on the other hand, might be reductionist (Papadopoulos, 2022, pp. 124f). It leads to an unrealistic suppression of existing permanent worldly intertwinement with anthropogenic influence, e.g. through economic ecologies, we cannot escape. The SOA explained this political notion of purity regarding *ecology/ies* in further detail.

Addressing the separation of registers, Papadopoulos speaks about the "quest" of "[t]he restoration of a general and generative experience of *ecology*" (2022, p. 126). All these frictional registers shape *ecologies* and create "experiences and social relations", a *general ecology* that is *generative* simultaneously (Papadopoulos, 2022, p. 125). The registers "all exist on the same plane and constitute the continuous experience of *ecology*". The *ecological* is thereby "at the heart of worldly existence" because beings experience their *ecological* existence through these generative ecologies *and* their relations in the worlds they are in (pp. 124f, Papadopoulos, 2022). The intertwinement with the *ecological* interests me when looking at how actors care through chemical practices. How are caring relations shaped through thinking of the *ecological*? How is the *ecological* generative in their thought on sustainability? How are chemical practices part of *ecology/ies,* affecting their situatedness? In the next section, I will discuss *obligation*s specifically towards the *ecology/ies.*

3.4.2. *Obligation*

Leaning on Puig de la Bellacasa (2017), Papadopoulos (2021, p. 49) defines *obligation* as not only bounded to "moral responsibility but involv[ing] a practical-material dimension and the urgency for action". One is obliged to the *ecology/ies* also in a material sense and must care in practice to not "face destruction". Papadopoulos et al. ask more explicitly about "*obligation*s and responsibilities" through our implications:

> "How are we implicated in the proliferation of damaging chemicals? How can we promote nonviolent elemental relations? In sum, what, [...] are our *obligation*s and responsibilities in mediating the distribution and redistribution of the elements?" (Papadopoulos et al., 2021, p. 6)

In these various aspects of destroying ecologies, such as the slow toxification of the living world through the complex and widespread distribution of substances, responsibilities cannot be traced back exactly or at all. However, the *obligation* of actors complicit with damaging structures is still relevant, even if not exactly traceable. It is important to consider the historically developed, industrial-academic chemical structures that (re)produce knowledge and material objects that are damaging. Within these structures, chemical practices were and are developed and conducted for "wars and colonial enterprises" (Puig de la Bellacasa, 2021,

p. 206) through the production of toxic gas as a weapon, for instance. Furthermore, industrial-academic chemical systems have led and lead to toxic *chemical residues* (Boudia et al., 2018) that will "remain toxic as they break down again, potentially forever" (Puig de la Bellacasa, 2021, p. 216). Considering this, the *obligation* lies in this historical continuity of destructiveness in this field of action. Following this, caring for changing toxicity structures is an *obligation* practice (Liboiron et al., 2018). Hence, the *obligation* is interlinked with *reparative justice*, as explained in section 2.2.3., because this kind of justice deals with the material dimension of care toward the damaged and toxified *ecology/ies* (Papadopoulos, 2021, p. 49).

In sum, an *obligation* is about material-practical aspects that are reparative and caring. However, it is not just a call for finding alternative chemical practices and entities while staying in the same academic-industrial realm as Stengers (2021) criticizes. Changing only chemical practices and materialities in the laboratory and production processes would understand *obligation* and responsibility as "[c]hemistry is used to" (Stengers, 2021, p. 28). It would exclude practices of changing ways of thinking and questioning the institutional circumstances. Puig de Bellacasa formulates it regarding capitalist white structures and their *obligation*s:

> "Maybe, then, embracing breakdown is really an *obligation* for those who hold the (white) privilege of enduring to release capitalized life force, so that others who are deprived of it can live [….] embracing breakdown has to be thought of intersectionally, in an ecosocially situated way, so that it targets the breakdown of infrastructures and institutions that most exploit the material conditions of life for most humans and nonhumans on Earth." (Puig de la Bellacasa, 2021, p. 212)

Therefore, Stengers asks if there "is another sense of *obligation* possible, which would shape chemistry differently—still a technoscience, of course, but belonging to another *ecology* than the academic-industrial network?" (Stengers, 2021, p. 29). The author demands a more questioning and humbler approach to these *obligation*s, accepting the shame and the harm, and not expecting to "cure" the world with technoscientific tools alone but to help where possible. Actors should care for the little things while thinking outside of their structures:

> "What remains is to create many small paths of healing" (Papadopoulos, 2021, p. 57)

As Papadopoulos points out, it is unrealistic to have the vision of "clean ecologies - not now, and not in the future" (Papadopoulos, 2021, p. 47). The before-discussed *slow activism* could then be a realistic but radical form of being obliged to *ecology/ies* (Liboiron et al., 2018). This approach describes "obligatory practices" and relations that are "intimate" and caring and involve small steps over time (Liboiron et al., 2018, p. 341). This careful slowness is based on ethical thinking and feeling like moral and societal responsibilities to reduce waste. It is not motivated by hoping for immediate big changes in the world(s) we live in. Rather, it is about

creating collective and cooperative connections that nourish oneself and the *ecology/ies* in small steps. This can lead to finding new material-practical ways that are less destructive and harmful–small steps, processes, and motivating changes. Furthermore, creating connections is not about perpetuating old power structures but transcending boundaries, like historically emerged industrial and academic ones. As Liboiron writes:

> "life flourishes through *obligation*s and solidarities among diverse collectives, human and otherwise" (Liboiron et al., 2018, p. 341)

These "obligatory practices" of *slow activism* "do not necessarily result in scaled-up material change but constitute material ethics at the immediate scale" (Liboiron et al., 2018, p. 341). It is, therefore, neither idealistic nor perfect.

Considering this characterization, which focuses on intimacy, feelings, small and slow steps, and not big transformative change, the connection to my study of day-to-day caring practices in the lab became apparent. It is something that I would like to discuss in the data section. How can these small practices and reflections be seen as *slow activism*? Is there bodily knowledge involved, and in what form? This is an important aspect of slow intimate activism and may include smelling, tinkering, and moving. Or is it about ethics rather than effect?

In turn, regarding my perspective on the chemical practices and actors of my study, I should acknowledge my embeddedness and involvement in the chemical entanglement within *ecology/ies*. Regarding my situatedness as a researcher, a careful approach involves avoiding "exercis[ing] an external, wholesale critique of chemistry or, on the other hand, an indiscriminate glorification of chemicals" (Papadopoulos, 2021, p. 47).

3.4.3. *Obligation* Towards the *Ecological*

In this section on *Chemistry, Care, and STS*, I rendered visible interdependencies between my research interest and the concepts of *ecology/ies* and *obligation*. It addresses how chemical reactions, institutional actors, human and non-human actors, toxicity, and harm are connected and present in my investigations. In which understanding is it possible, according to STS literature, to care in new ways? The conceptual lens of *obligation* provides a possibility to think about the direction of care, what to care for, and how to care for it. This means caring in a material-practical way, in small but collective steps, and resisting damaging systems like petrochemistry. The concept of *ecology/ies*, in return, helps us understand how we are interdependently connected to other living beings, experiences, and environments while considering caring relations in chemical practices. Aspects of care for *ecological obligation*s also become important in the laboratory, specifically in my case. Concepts in

Laboratory Studies, like transcendence, scale, immanence, and technological determinism, are also crucial. How can research scale up the production of benign alternative anthropogenic chemicals, and with which issues and risks is it connected? How can we regard the immanent conditions of the lab, like resource and energy requirements, while being obliged to *reparative justice*? How is a technologically deterministic viewpoint, like ideas of green technological fixes, present in the statements of the participants?

3.5. Summary of the Theory Chapter

In this chapter, I have discussed two theoretical fields of STS–Laboratory studies and *matters of care*–, their interdependence important to this research case, and the connected specific concepts of *obligation* and *ecology/ies*. This complex theoretical approach will help me understand and discuss my data in a more nuanced way. The strand of Laboratory Studies offers me resources for conceptualizing the participants' views on research and analyzing the relations and practices of non-humans and humans. Two theoretical approaches are of particular importance to understanding my data. Firstly, how knowledge processes in chemical laboratories can be theorized. This is connected to immanence in questions, such as research conditions and calculations, and transcendence in questions, such as how the synthesis of a product can be upscaled and implemented in industrial production. Secondly, the understanding of technological determinism sensitizes me to different thought patterns of participants regarding the role of modern chemistry in *ecology* and society. Laboratory Studies in connection with *matters of care* allow me to analyze the emotional, affective, and ethical layers of the assemblages of practices, actors, and relations in the participants' research. The concepts of *obligation* and *ecology/ies* are helpful lenses for the Green/sustainable Chemistry endeavors and the viewpoints and approaches of the participants towards the *ecological* effect of their doing. In the next part, I will introduce and explain my Research Question.

4. Research Question

I will contextualize and pose my research question and the accompanying sub-questions in this section. Political and societal attention towards hazardous pollution, which affects the health of living beings and the planet, has increased over the last decades. Therefore, I am interested in the growing awareness of sustainability in chemical fields responsible for polluting *ecology/ies*. Green/sustainable Chemistry interests me here because of the complicity with and resistance to these *ecological*ly affecting structures. Since I lived in Austria during my research, where chemical research and industry represent a substantial part of the economy, I focus on a Green/sustainable chemical laboratory in this national scope–specifically, the Viennese context. The group deals with chemical pollution in multiple ways in their everyday laboratory practices. This research opportunity led me to the following proposed questions:

How do actors practice care in the context of sustainable chemical practices in the laboratory?

- *How is sustainability understood and approached in the everyday laboratory and the discursive practices of the researchers?*
- *How do actors care for chemical pollution through their practices?*
- *For whom and what is (not) cared for?*

I have chosen to empirically investigate this case through the theoretical lens of *matters of care* and the strand of Laboratory Studies within the Viennese context. My methodology consists of interviews with involved actors like the chemical researchers of the lab and ethnographic field visits. A constructivist analysis, complemented by a multisided ethnographical approach, enables me to map the complex caring relationships between living beings, toxic molecules, chemical knowledge, and production practices. My analysis reveals how these relations enact chemical pollution and how the anticipated future demands action. Chemical laboratories as sites connect exactly these dots. Researchers use chemical products, are responsible for wasting chemical products, and need to be conscious of the toxic chemical products they are using. They research and produce laboratory artifacts, which are only possible through chemical reactions. Chemical pollution in the laboratory poses health risks for the employed researchers, assistants, and cleaning personnel. Furthermore, chemical pollution can also be hazardous in the broader *ecological* surroundings and concerns the health of all living beings. How do non-human and human actors connected to the lab care for these risks? What are their concerns? How do researchers treat and construct chemical pollution in day-to-day activities? Do they change/stick to behaviors to ensure sustainability in their lab? These questions will be discussed in the analysis chapter.

5. Methodology

I write this chapter taking inspiration from Silverman (2017), who highlights the importance of representing research as a process and the researcher in their positionality. For this, I will describe my practical and theoretical considerations and my practices. In the first section, I will explain the methodology of multi-sited ethnography, including interviews and field visits that I conducted in the laboratory. How is it connected to my theoretical framework? What is my underlying methodological approach? In the following section, I will chronologically explain the different practical steps and reflections involved in my research process. How did I get access to the laboratory? How did I prepare for the research? What kind of pre-situations to the actual interviews and field visits were there and what does it say about my and the participants' positionality? What were situations in or around the ethnographic process influencing my research? What were the last pre- and post-considerations on language and the translation from English to German in the interviews? In the third section, I will focus on ethics, which is also an important part of my methodology. What is relevant regarding participants' privacy, their science's intellectual property, and my involvement in the research question? Afterwards, I will address the handling of the data, including methodological approaches towards transcription, analysis, and discussion of it. This includes using the chosen computational program MAXQDA, my coding process, and underlying theoretical considerations. Finally, I will briefly summarize my methodology before analyzing the data.

5.1. Choosing Ethnography

In this section, I will introduce my overarching methodological frame, a multi-sited ethnographic approach, and the related theoretical considerations.

The text by Knorr-Cetina (1995) discussed in the theory section, which brings together an overview of laboratory studies with empirical examples and theoretical approaches, is a conceptual resource for my ethnographic study. Based on the strand of Laboratory Studies, the central role of my methodology is dedicated to empirical and social questions instead of philosophical and scientific ones (Knorr Cetina, 1995). The participants' interest in finding ways to include sustainability in chemical practice and reduce chemical pollution matches the discussion by Knorr-Cetina describing *unfinished knowledge,* which is "the province of laboratory studies" (Knorr Cetina, 1995, p. 141). From this STS tradition, it is important to highlight the processual and partly messy character of chemical practices. Through my ethnographic study, I also want to gain a critical and fine-grained perspective on changing chemical research in an institutional setting. What is possible, and how does it apply in practice? What does sustainability mean for the participants in chemical development and research? What can it mean for *ecology/ies*?

In my research, I applied the methodology of multi-sited ethnography. Marcus describes this approach "as mapping a space or field of social action found in the field itself through closer work and collaboration with certain subjects" (Marcus, 2011). For this endeavor, I combined qualitative researcher interviews with site research. In this way, I can investigate "through closer work and collaboration" the "social field", which, in this case, is the laboratory (Marcus, 2011). This participation and observation practice focuses on social relations and fits into the tradition of laboratory studies (Knorr-Cetina, 1995).

I studied their website for ethnography preparation, which also changed its presentation during my fieldwork. However, my focal point is their relation to their work.

Following Jensen & Laurie's introduction to the different methodologies of qualitative interviews, I designed the interview guideline using an in-depth and semi-structured method (Jensen & Laurie, 2016c). This helped me construct a conversation to specifically address my research questions while getting the opportunity to expand the conversation. As I am not an expert in the field, I stayed flexible in asking spontaneous questions during the interview that might be relevant.

I take inspiration from the laboratory study by Pinel et al. (2020) regarding field visits. In this research, I use ethnographic field notes to illustrate the relationships and practices in the lab; I then include and analyze specific moments or autoethnographic reflections. This way, my interactions in the lab and my thoughts during the research process are represented in the final work. I chose this approach because reflecting on my position is relevant to the conceptual

framework of *matters of care* and myself. The ethnographic field notes further help me contextualize the interview data and vice versa since the participants are the same in the interview and the field visits. Also, the themes and practices discussed and observed will overlap.

During field visits, I use sensual experiences, like taking in the atmosphere, listening to music played in the lab rooms, seeing the experiments being done, walking around, and more. Drawing from Pink's text (2011), where the author focuses on the anthropology of the senses, my "embodied and sensory perception" enriched my ethnographic endeavor (Pink, 2011, p. 266). Especially when I focused on the atmosphere and my feelings in the room during field visits, it enabled me to distance myself from the western five-senses model I grew up with. The five-senses model separates sensorial experiences into the constructed categories of smelling, hearing, feeling, seeing, and tasting (Pink, 2011). Therefore, it simplifies the representation of my diverse and complex embodied experiences as a researcher. Eventually, I cannot avoid sensorial experiences, which are "neurological information [which] becomes differentiated into categories" (Pink, 2011, p. 266). Nevertheless, I try to be as little reductionist as possible while staying within the scope of a master thesis. My "multi-sensorial" approach in the research is further relevant to post-ANTs such as *matters of care* (Puig de la Bellacasa, 2011; Michael, 2017b, p. 133) because I interacted with the actors by being physically there and (un-)consciously sensing things beyond information retrieved through classical interview questioning and ethnographic notetaking (Michael, 2017b). Furthermore, I highlight my body as a means for bodily connections, which I discussed before as an important part of STS considerations over chemical toxic connections (see, for instance, Murphy, 2017).

5.2. Conducting my Approach

In this section, I will guide the reader through the various steps of my multi-sited ethnographic approach. This includes gaining access to the laboratory — the site of interest for my research — and preparing and conducting interviews and lab visits. I will also discuss my positionality and considerations of translations between English and German.

5.2.1. Gain Access

To receive access, I emailed the principal investigator (PI), the professor leading the group, about my research plan for March. PI is generally used in natural science and laboratory contexts, describing "the person leading a scientific or engineering project" (Cambridge Dictionary, 2024). I asked for a meeting for further discussion with a summary of my research interests. The PI answered relatively quickly with an invitation to their office and a warning that they were doing "hardcore synthetic chemistry". When we met, I understood that they thought I wanted to do a diploma thesis at their lab - not about their lab. This was the first indication that this lab leader and the lab culture promoted here strived for interdisciplinarity because I had already made it clear from the beginning that I am a social scientist with a background in molecular biotechnology. After clearing up the misunderstanding, I was allowed to interview them and the PhD students who were actively working on the research projects. It became clear that there were no laboratory assistants in that lab. I asked to be in the lab as an ethnographic observer. In the end, it was about a thirty-minute-long conversation. To give an insight into this first encounter and research experience, I will share the following excerpt of my autoethnographic reflection that I wrote afterward on the same day:

> " [...] We walked through the laboratories with the dog and eventually sat down in a bigger room, where one of the research group members was working on a computer but would leave soon.
>
> The PI told me they understood that I wanted to do a "Diplomarbeit" at their institute. This first misunderstanding paved me the way to explain my research plan and my own situatedness. Later, we discussed if it would still be okay for me to observe the work in the laboratory for a couple of days. Practicing there in the laboratory but not working there as an employed person would have been an issue. However, observing, making notes, talking to other employees, learning about the practices through other researchers are things I can do in the laboratory as a non-directly involved person.

[…] The other part of my ethnographic work would be as planned 3-4 interviews with the PI and everyone working on the project that I am interested in, which is the reduction of carbon dioxide through using it as a replacement for carbon monoxide in synthetical reactions. Since this project receives the most funding, which is the ERC Grant, that is where most work is done, and most people are working on, as the PI explained to me. This was an interesting piece of information. Not only would it provide me with more potential material to analyze and write about, but it also shows one of the logics of the laboratory, that funding (possibilities) influences the focus of the work."

5.2.2. Writing the Questionnaire and My Ethnographic Guidelines

For the ethnographic guidelines and my questionnaire, I first wrote what came to my mind and then gave it a more explicit structure. I could rearrange the questions according to topics after writing them down. According to my line of thought, they already had an underlying structure, and using my research question chapter, I could add or specify some of the questions. After getting feedback from my supervisor and my colleagues, I designed some questions to be more open. Another recommendation was to not use the word *care* as often as possible in questions but to rephrase the questions without this specific term. Care has a specific theoretical meaning in my thesis because it is related to the concept of *matters of care,* which can differ from the understanding of the participants (Puig de la Bellacasa, 2011). Nevertheless, I used the word in smaller amounts to analyze the interviewees' interpretations of *care* as a concept and practice.

5.2.3. Positionality and Waiting Field Situations

In the following, I will speak about the time three months after the first preparational steps, when I met the participants in person and had a second pre-ethnographic visit in the laboratories. I will then relate this to the methodological conceptualization of such encounters, leaning on Folkes (2023). This is inspired by an assignment for my course Introducing interviewing - Thinking and practicing qualitative interviews, where I discussed a related situation from the Winter term 2023/2024. This is a fieldwork note about the first personal interaction with the research participants besides the PI in July:

> I wrote another email in June asking if I could move the interviews to July, from autumn, as previously discussed. I initially quickly received an answer, but when circling back for specific dates, the PI could not be reached via email or phone, which was unusual compared to my previous experiences. After a month without an answer, I went directly to the lab and was told that the PI would only be there the next day. The next day, I was hustling from one seminar at my university institute to the lab and then back to go back to the lab, and I ended up with only about twenty minutes to talk to the PI. This was fortunately successful, and the lab leader made an appointment with me for an interview. Then, they passed me on to their PhD students for interviews and lab ethnographical work. Three of them stayed to talk to me after the PI left: one immediately made an appointment with me for an interview and to observe them on the same day, and another told me I should contact them via email about a concrete appointment because of the currently busy schedule that they could not currently access. The third did not seem to have time for conducting interviews, which is typical for PhD students as balancing research and daily life can be very stressful with this occupation. Later that day, I scheduled a date for an interview and an observation via email with the second PhD student, who had shown interest.

I will relate this moment of gaining access to the field with Folkes's (2023) conceptualization of *waiting field situations* and *kitchen table reflexivity*. The latter concept based on Kohl & McCutcheon (2015), refers to everyday reflection with colleagues about positionality. In my thesis, I extend this concept by leaning on *waiting field situations (*Folkes, 2023)*,* where I engage with the research participants in reflective conversations before the interview starts.

To talk about this situation as a *waiting field*, I first need to reflect upon aspects of my positionality related to questions of access. I am a white German-speaking academic, non-disabled student situated in institutional academic structures in which ableist, racist, elitist, and other forms of discrimination and gatekeeping exist (Hinton-Smith & Padilla-Carmona, 2021;

Manzanera-Ruiz et al., 2024; Morina, 2024; Ressa & Danforth, 2023). However, it may not apply fully to this research group, which I cannot know as an outsider. I was introduced to the PhD students by their supervisor, which further helped me gain access to the research field.

When I met the PhD students in the *waiting field* I introduced myself and explained that I was interested in interviewing them (Folkes, 2023). The potential research participants were primarily interested in my academic background - being surprised and seemed partly sceptic (as described in examples of Folkes' research as well on p. 1311, 2023). I had to elaborate on my research interest to them to gain their trust and interest. This experience differed from explaining my research to students in the STS fields or my friends who studied molecular biotechnology. It is different because the possible participants are part of the research I am interested in and know much more than I do in this field. At the same time, they do not know the conceptualizations and methodologies of social science that I wanted to apply. I reflected on my communication strategy for my research participants in the interviews, which potentially influenced the interviews. I further explained to them what the consent form would look like, what would happen to the data, and why I wanted to speak with them.

The way the researchers, who seemed to be in my age range, talked to me was mostly informal and relaxed. This might be connected to our similar age and my background in molecular biotechnology, which has similarities because of my experiences working in the laboratory, my social environment of friends working in biochemical areas, and, therefore, my comfort in this situation. I was also able to convey how I relate to them (similar background) and get a better feel for how I can explain the significance of the research to them. I can only speculate how this *waiting field situation* informed the positionality of my research participants.

5.2.4. Interviews, Lab Visits, and Last Preparations

In this section, I will talk about the time shortly before, in between, and after the fieldwork. Before the first interview started, I met my friends from my previous studies in molecular biotechnology. They have lab experience (in molecular biology/life science labs) and took the time to review my questionnaire. It helped me to get their perspective and accordingly adapted a few questions. Later, I noticed some of their predictions about the interviewees' reactions toward specific questions were accurate. For instance, there were not too many questions, and I could add more since natural scientists tend to give short answers (the interviews were shorter than I thought, with around 30-40 minutes and 60 min with the PI). These friends also predicted that researchers would have trouble understanding what I mean when I ask what they care for. Although helpful, these pre-consultations with friends and colleagues, as described earlier, influenced my approach. Conscious of this, I aimed to be open to the outcome and see this advice and predictions as helpful but not consistently accurate.

On the second day of my lab visit, during lunch, I met another PhD student interested in my work in the lab. A week later, when I asked for another interview, the research leader forwarded me to this PhD candidate.

In our subsequent meeting, the lab leader suggested adding another individual to my interviewee roster. However, I decided against it at that moment–being overwhelmed by the last week of laboratory visits and interviews. The next day, I reconsidered and wrote to them about my wish to interview an additional researcher. This showed me how my intuition and (over-)thinking shaped my research path, as the interview was rich and extended my analysis. The field notes contain my impressions, reflections, and observations from ethnographic lab visits. I wrote in my small notebook during and between the interactions what came to mind and what seemed relevant at that moment. I transcribed everything into a Google doc for the following two weeks, including additional memories. I did this consciously before my summer break to avoid forgetting about interesting details and impressions.

5.2.5. Translation (Re-)Considerations:

One unexpected issue was the linguistic challenge of translating the word care from English to German. In this research, care is understood through the lens of *matters of care* (Puig de la Bellacasa, 2011) as a form of practice based on emotional, affectional, maintaining, and/or interest-including relations. In the interview settings, I translated this term into German for two participants, with whom I had agreed to do the interviews in this language. Finding a proper equivalent German word for it is difficult with the concept of *care*. In hindsight, I was *careless* with this wording issue for my first interview. I made a mix out of “sich um etwas kümmern” (= to [take] care of sth./deal with sth.) and “achten auf” (= take care of/watch out for), which is my interpretation of this word. More precise would have been to add “pflegen” (=I care/maintain) and “sorgen” (=I care/worry). I realized this *carelessness* even more when transcribing my thesis and researching the multiple possible translations of the word. In the interviews themselves, I primarily relied on my spontaneously formulated translations. I will consider this during the analysis and discussion of the German-held interviews regarding their relation to the concept of *care*.

5.3. Ethics

In this section, I will discuss my ethical considerations regarding the conduct of this study. This includes how I approach sensitive data regarding unpublished knowledge, how I retrieved consent for the interviews, and further thoughts on my research practices and interactions with them. Lastly, I will end with a vignette about my inner ethical questioning.

To deal with sensitive and unpublished data regarding knowledge production in synthetic chemistry, I did not document experimental designs in their specificities or synthesis steps in my ethnographic notes. Afterward, I asked the researcher, whom I observed in the labs, which pictures to delete and which to keep. In this way, I was transparent about the collected data with the participants and let them be the experts on what sensitive data is and is not. I also inform them, in general, via email, when I plan to use citations from the interviews in my master thesis.

For the interviews, I generally retrieved informed consent from the participants as described by Jensen & Laurie (2016b). At the beginning of the interview, I repeated that they could stop the recording, skip questions, and decide what could be published. I also explained what I am interested in writing and researching and the institutional context of my research project. Further, I explained that I am a student at the University of Vienna and writing my master's thesis around this study case. This is relevant because then the participants can estimate the consequences the research might have for them. When it came to the field visits, I tried to hinder their work as little as possible and ask questions when they had seemingly time for it.

Regarding clear communication on my motives as a researcher, it was important to me to make clear what I am interested in regarding the practices in this laboratory from a social science perspective because the participants inquired about the role of their work in my research results. I highlighted to them that my research is not to bring their field forward but to engage critically with their practices in Green/sustainable Chemistry and care for chemical pollution. Following TallBear's essay on ethnographic research, my critical STS perspective can contribute to an exchange between this research field and Green/sustainable Chemistry (2014). My ethical motive is not to conduct research as a service to one of the fields but rather an exchange on different levels, from interviews and waiting-field situations to writing this thesis, emailing my progress, and finally publishing it. I aim to be on equal footing with the other actors in this research (TallBear, 2014). Even though the relationship between me and the research participants has hierarchical aspects, like that I can interpret the data and am writing this thesis without other actors actively participating in writing, there are other resisting aspects. I care for knowledge production that *thinks-with* the participants' perspectives and experiences, not to give knowledge back or receive data but to reflect jointly on issues of

chemical pollution and alternative practices (Puig de la Bellacasa, 2012). I am embedded in the connection between chemical and STS practice of knowledge production through my biography. My mixed academic background and my experiences in researching for this thesis in the field of Green/sustainable Chemistry coming from the field of STS enriched the outcome of this work. The thesis process further imprinted me intellectually as a scholar and morally as someone being part of polluted *ecology/ies* (TallBear, 2014).

The following vignette is an insight into my approach to the ethical questions coming up during the research regarding my role and reflexivity:

> *One thought or feeling or anxiety I carry with me while doing this study, also before but especially induced when* ***field-working, reading, writing, and thinking*** *about my case, is that I might* ***be a hypocrite.*** *I want to make these four just mentioned leading research practices into something helping me to cope with this anxiety, which is sometimes valid and sometimes irrational, mainly at the same time.*
>
> ***Reading.*** *First, the text by Shotwell lets me breathe out but also inspires this reflection in the form of a vignette because the author names hypocrisy concerning our daily dealing with toxicity. How I compromise, how I am complicit, and how our only way forward to seriously care for these worlds is to start from there and acknowledge complicity and compromise.*
>
> ***Thinking.*** *Reading this makes me think. Going on my everyday activities while working on this thesis makes me think (about my instant coffee, the snacks in-between, heating, and a new computer but with a "sustainable" certificate). Having these different moral, social, and ecological obligations in mind while working makes me think. It makes me think about my limitedness, how I compromise to impactful behaviors for this work (like buying a new computer), and how I am complicit (my privileges of doing this work and getting this education).*
>
> ***Writing.*** *Writing this vignette and being vulnerable is a way of coping because to write, I must reflect upon my actions and moral feelings. I can think in a way that shares my thoughts with the paper and others about these wicked situatednesses in the mess we are constantly creating.*
>
> ***Fieldwork****: I talked to the participants, who acknowledged that what they are doing is "trying their best." They know that things are still unsustainable, "everything is toxic," and that it is one step at a time and a collaborative approach.*

I can breathe out, acknowledge the feeling of hypocrisy, and know that complicity and compromise are not something I can escape but only something I can work with, hoping to take the next step.

"We're hypocrites, maybe, but that derogation doesn't encompass the nature of the problem that complexity poses for us" (Shotwell, 2016, p. 6)

This sentence inspired me for this vignette because it debunks hypocrisy as a "derogation"; we should not be stopped by it because the issue is too big to focus on that human feeling. It is not about hiding or not being a hypocrite but moving forward **with** it. As described in the concept of *matters of care*, it is a form of caring **within** to accept the inescapability of *complicity* and *compromises.* Here, it is important to differentiate the unequal distribution of harm and benefit between humans and their anthropogenic structures. Hence, the subsequent *obligation* and responsibility tied to complicity towards capitalist and colonialist structures is differently distributed among groups of humans (Shotwell, 2016). I would see myself in a more obligate position because I am a white, educated, middle-class person who consumes synthetical-based products (e.g., medicine, plastics). Not that it is possible not to be complicit and compromised–I am also dependent on medicine and capitalist structures to survive and live. However, it is important to clarify this position and the accompanying feelings that come with it because they were also a strong personal - perhaps selfish - motivation to research this topic and better understand the situation and what could be done and be critical.

In this section, I have summarized the different pragmatic steps to ensure ethical interaction between me as a researcher and the participants of this study. These included dealing with sensitive data, informed consent, and a transparent and convenient research presence for them. Finally, I reflected on my positionality and motivation to study this topic, which is important to understand my own moral and ethical considerations.

5.4. Transcription and Analysis of Data

This section will discuss my methodological approach to handling the data retrieved from the interviews and ethnographic settings. First, I will describe my process of preparing and transcribing the data. Second, I will explain my considerations for my analysis. Following up on this, I will lay out my computational approach and thinking in the subsequent three sections regarding coding, formatting categories, finding themes, and writing memos. Through this, I can introduce how the collected data becomes helpful in my methodological approach.

5.4.1. Transcription

After my fieldwork, I took a break in August and transcribed the interviews mid-September. I used MAXQDA for the transcription after I learned that for Inqscribe to save data, I would need to pay for a license. A friend, an STS student, recommended this software instead. The transcription process went relatively fast in comparison with what I expected. The first day of downloading and getting to know the software made me believe I needed a few hours to transcribe five minutes of the record. In the days after, I transcribed more smoothly; it became a practice where I became more and more trained to do it. In this first practical step of data processing, I started reflecting on recurrent themes and the participants' discursive practices. In parallel, I started making pre-written notes. Every day, I transcribed, noted some comments about topics and open questions, and copied/pasted excerpts of the transcribed interview. These excerpts are either of interest to my research or are somehow unclear to me because of the answers or my formulated question. This was a pre-step to my analysis, which I will describe in the following, starting with my conceptual approach towards analytical practices.

5.4.2. Methodological Approach to Analysis

In the analysis, I will take a critical constructivist approach to treat what the participants have said in the interviews as “displays of perspectives and moral forms” (Silverman, 2006, p. 144). Through this, I can account for my posed question about the discursive practices of the interviewed people due to their background, beliefs, and situatedness. My notes collected in fieldwork research help contextualize the co-produced knowledge of the interviews and analyze the constructivist approach towards chemical pollution. As I view the interview interactions as incidents I can analyze regarding re-occurring/connecting themes, I use a topical approach, as Bryne (2018) recommends. This also connects to the constructivist

approach in laboratory studies in general since I draw inspiration from them (Knorr-Cetina, 1995).

To analyze the assemblage of multiple practices in the laboratory and their caring dimensions more in-depth, I will draw on the text by Pinel et al. (2020). The authors look at the caring dimensions of data practices in proteomic labs. Concerning the *matters of care* (Puig de la Bellacasa, 2011) lens, I can problematize the actors' relations regarding affection, attention, and emotions. Further, I am attentive to the specific practices of the lab group while analyzing the fieldwork data.

5.4.3. Coding in MAXQDA

In this section, I will describe my coding process, which I conducted using the computational program MAXQDA, guided by already formulated deductive themes and allowing me to define further categories and themes.

I am following a topical approach to analyze my data (see Rivas, 2018). Jensen & Laurie's (2016a) chapter on analyzing qualitative data in their methodological book "In Doing Real Research. A Practical Guide to Social Research" is helpful as well. I had several exchanges with STS study colleagues and my supervisor throughout the process to help me better understand coding and overcome my initial anxieties. In the beginning, I wrote a small plan based on these texts and the first exchanges; some parts changed, and some stayed the same. Ultimately, I used a deductive-inductive mix of the themes I had in mind–Care and Sustainable Chemistry–with the openness of generating new themes through open coding (Rivas, 2018, p. 433). In MAXQDA, I ordered the interview data in files. Then, I imported my fieldwork descriptions into the software and formatted them for the coding part (Jensen & Laurie, 2016a, p. 252; Rivas, 2018, pp. 448ff).

After carefully coding line by line the first interview, I decided that I would not do as planned, already another "pass" on this first interview. A pass means to go through the data with the preliminary codes. I continued the other interviews (Jensen & Laurie, 2016a, p. 254). I sorted codes into subcodes between every interview and merged them where needed. The subcode classification also leans on the two deductive themes with preliminary sub-categories. Figure 1 shows a mind map of the first ideas in my notebook. I did a "pass" through all the interview data when my coding sets were transformed through these merging and sub-classifications and needed to be checked to see if they were still applicable to all interviews. I then applied this set for my ethnographic data and opened a new distinctively colored set of

codes and subcodes that I retrieved from additionally open coding this part. There, I passed through the data to check the application of the codes.

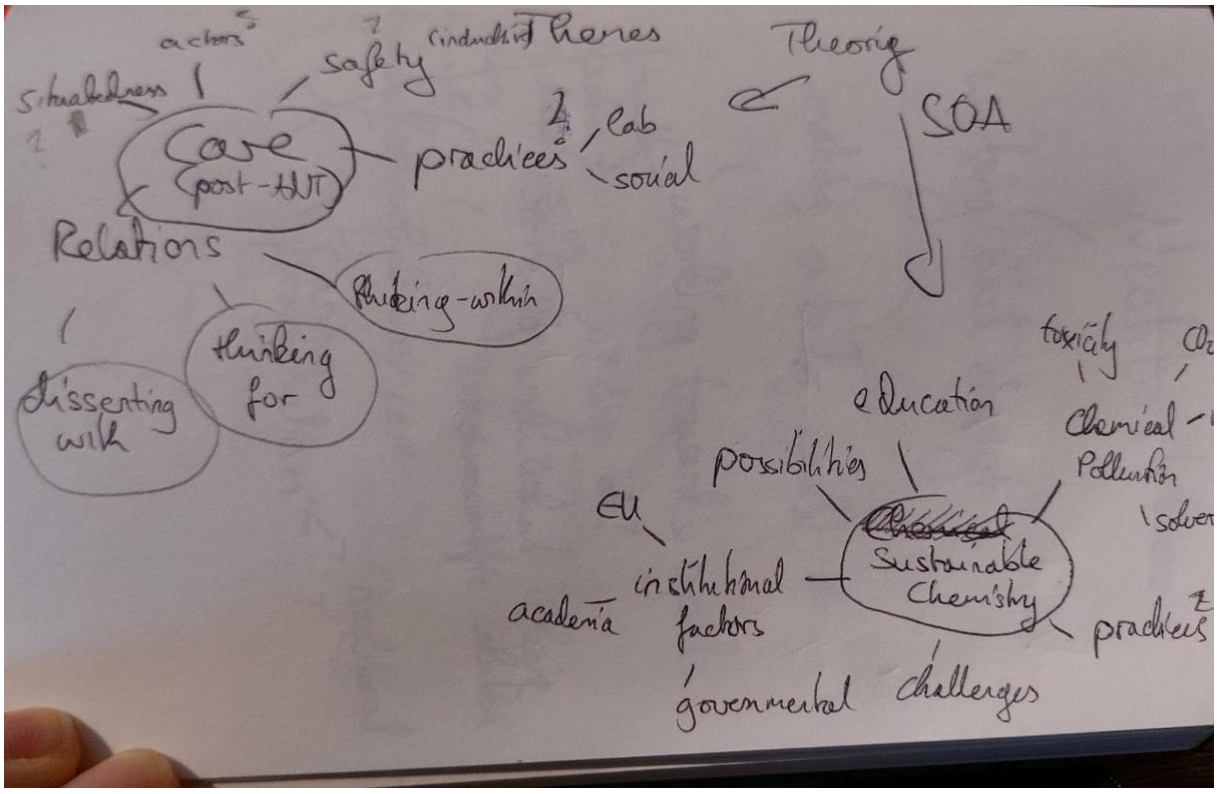

Figure 1.: ***Mind Map of preliminary deductive themes, categories and themes***

Building upon the open codes with the help of spider diagrams (Fig.1), I formulated categories (Rivas, 2018). Then, I linked my deductive themes of care and Green/sustainable Chemistry with these categories to facilitate a better understanding. Furthermore, I got new themes by analyzing the categories derived through my inductive open coding approach (Rivas, 2018, fig 20.3, p. 440).

5.4.5. Memo Writing

Throughout the process of transcribing and coding in MAXQDA, I extended my notebook - filled with ethnographic notes - with memos in the form of graphs and bullet points. Jensen & Laurie (2016a, p. 252) highlight this practice to keep track of, e.g., “issues,” “interesting connections” to “other participants,” and “links to the theory” in the process of analyzing the data to have sources for the writing part. In MAXQDA, I wrote notes in my logbook and comments/memos for the codes. A third source of my thoughts in the analyzing process is the Word document, which I used in the beginning in parallel to the transcription I

described earlier. Ultimately, I brought these memos together to help me order my thoughts and get them on paper. I think the variety of site notes I used made it less clearly arranged but helped me to note thoughts more spontaneously and in diverse ways, which helped my creative flow.

5.5. Conclusion on My Methodological Approach

In this chapter, I have shown the various practices and theoretical considerations involved in my methodology for this study. In line with the STS tradition in laboratory studies, I explained how I used an ethnographic study with a constructivist approach regarding preparation, data collection, and analysis. I covered the various practical steps involved and how they are connected to positionality, exchange practices, and linguistic questions. Furthermore, considering complicity and compromises, I reflected on ethical questions and my approach to the practices. In the end, I focused on my transcription and analysis process, from where the themes emerged that I will discuss in the next chapter.

6. Analysis

In this chapter, I will present and analyze the results of my research based on the themes that emerged from the coding process of the ethnographic data. This will address my research questions through two entangled angles: knowledge practices of *matters of care* (Puig de la Bellacasa, 2011) and Green/sustainable Chemistry. Therin further themes emerged: with analyzing observations and statements on toxicity, waste and pollutants in the day-to-day laboratory research I approach the question of *how do actors care for chemical pollution through their practices?*. Personal relationships and collectiveness are parts of the here presented fieldwork data to understand practices of care and the interrelatedness within the Green/sustainable Chemistry community. Moreover, I will focus in this chapter on different institutional, financial and political actors to understand the context in which the researchers practice care. A recurring theme in this chapter is also the (self-)reflection on the topic of sustainability, the role of chemistry thereby and/or its limitation.

6.1. Care

To address my main question, *how do actors practice care in the context of sustainable chemical practices in the laboratory?* I am analyzing aspects of care I observed, experienced, and exchanged in my ethnographic fieldwork during the lab visits and interviews. I will outline this analysis based on the background of the theoretical conception of *matters of care* (Puig de la Bellacasa, 2011). When discussing knowledge practices, Puig de la Bellacasa outlines three modes of thinking based on care relations, which are intertwined and overlapping: *dissenting-within, thinking for, thinking-with* (Puig de la Bellacasa, 2012). I will apply these modes of *thinking with care* in the next section when analyzing my empirical data on practices and relations in the laboratory. By relations, I mean not only interest or power but also care relations within a network of actors (e.g., supporting friendships, care for their experimental setups, etc.). The participants describe these diverse relations regarding their project and experiments, like enjoyment and inspiration, community and sustainability research goals, and internal social relations. In the following, described practices and relations from the data will not be strictly categorizable and will be more freely interwoven with these variations of *thinking with care*.

6.1.1. Thinking-For

In this section, I will describe practices of caring and thinking for others, which rely on relations between actors and the constructed *other(s)*. In the following, I will analyze statements on *thinking-for* the future, the environment, and people affected by safety risks.

6.1.1.1. Thinking-For the Future

Thinking-for a future where the solutions can be applied is described by one participant in this statement:

> "the topic of circular economy of reuse is something that will become more and more important and that is something always to keep in mind, also for my research what can be used and what solutions we could provide **for the future"** (Record 2, Pos. 70)

The carefulness here can be seen in the way they describe the processual character of an economy "becom[ing] more and more important" and counting a time factor in for finding "solutions we could provide for the future". However, the *other*, the future, seems distant in this statement, and the now is influenced by the ideas of a "circular economy." Another interviewee underlines the involvement:

> "Yes, so in any case perhaps that it is at least a small contribution to further development and that the industry can become more CO_2 neutral, so to speak, or that there could be a kind of circular economy" (translated, Record 4, Pos. 42)

Other complementary visions for the future of the economy and production they want to contribute to are mentioned as well - a "CO_2 neutral" industry. In the statement above a specific vision for the future is presented:

> "yes, exactly, so the dream, of course it's a utopia at the moment, but that there could be a factory where you practically switch off the CO_2 and then use it directly, there are of course other technologies to reduce CO_2" (translated, Record 4, pos. 40)

However, what practical and near future do these ideal theoretical scenarios mean? The influence of their research in the now - bringing ideas and inspiration for "solutions" while also producing pollution and waste through their practices anticipating contributing to alternative economies–has impacts on this practical, more immediate "future" (Record 2, Pos. 70). They *think-for* the future, which affects the now and the future as well in unwanted or seemingly contradictory ways (pollution/waste/resourcefulness). However, these care practices are important for their ongoing guidance and motivation for their research, with the

hope that some small contributions will still be made. It can be argued that this is a form of *slow activism,* where the ethics (trying for an alternative way of doing things) are more important than the immediate effects, accepting the overpowering presence of chemical pollution and toxicity in the anthropogenic conditions of our *ecology/ies* (Liboiron et al., 2018). In the next section, I want to look at practices of *thinking-for* the environment, which is mentioned in this statement:

> "what I am researching might have an impact on the environment" (Record 2, Pos. Pos. 76).

6.1.1.2. Thinking-For the Environment & World & Humanity

In this section, I argue that the way the laboratory researchers speak about having the goal of application is a way of constructing otherness. In the interviews, they underline their motivation to achieve something that helps others and has a positive influence on the environment, the future, and society (all distant but related entities). One participant is referring to a humanistic worldview by saying:

> "I'm generally interested in all the topics I'm involved in, just to generate some kind of meaningful input for the world, for humanity, for myself" (translated, Record 1, Pos. 18)

They are relating themselves in caring relations to their *ecology* ("world"/ "humanity"), which also implies they are situated in the described outside world and affected by their practice "to generate some kind of meaningful input" as the second part shows. Concluding the interview, the participant pointed out a situation they had with their former Bachelor supervisor to answer the question of what they care for. The advice from this supervisor on the question of what is "right" or "wrong", was the following:

> "you're doing it to the best of your knowledge and belief anyway, that's all you can do" (translated, Record 1, Pos. 92)

It shows again the motivation and drive coming from this *thinking-for* practice while acknowledging the limitations of their work and knowledge. This is an aspect that will be discussed further in the *dissenting-within* section. Before, I will analyze *thinking-for* practices in the laboratory considering safety issues.

6.1.1.3. Thinking-for in Laboratory Practice

A *thinking-for* practice closer to everyday life as a researcher is the constant caring and being concerned about safety issues, which will be described in this section. These practices are most prevalent in answers regarding what the interviewees care for in their work. Caring for safety was also visible in my ethnographic work when accompanying participants in their laboratory practice. This caring for safety is partially a *thinking-for* people that are directly in their work environment, e.g., other researchers. One participant mentioned while they were showing me their bench that they put needles into one extra canister so that the cleaning personnel would not hurt themselves when picking up the trash (fieldnotes_1, Pos. 19). More generally, one participant focused on the aspect of "not putting ourselves personally in danger" as the "core problem", regarding the care for others, which includes their safety as well (translated, Record 4, Pos. 138).

6.1.1.4. Thinking-For in Conclusion

In this section, I have shown two different areas for *thinking-for* practice. First, how they think within their work for the future circular economy and industrial application. Secondly, the participants address the safety of others and themselves in their day-to-day laboratory practices in the interviews. I read caring-for in their statement and practices as a motivation and driver to do their chemical practices in the way they are doing them, their searching for alternative ways of doing them, their investment in education, and their exchanging and connecting with different fields (e.g., politics). I want to highlight in the next passage aspects of dissenting-within the caring relations they are in.

6.1.2. Dissenting-Within

The following discussion on the participants' statements will lighten practices and reflections about *dissenting-within* caring relations, which are important since new relationships are created when old relations disconnect. I will start by reflecting on their limitations in caring relations regarding Green/sustainable practices and *dissenting-within* academic chemistry structures in general. Afterward, I will focus on output pressure in academic culture. In the last section, before I conclude on these practices, I will discuss the maturing process within the Green/sustainable Chemistry Community.

6.1.2.1. Dissenting-Within Green/sustainable Chemistry and Their Ideals

I will also discuss the repeatedly highlighted limitedness of Green/sustainable Chemistry in the Sustainability theme. The participants describe it as not being sustainable but "more sustainable than other things" (Record 3_2, Pos. 5). Answers regarding this aspect often follow up on my question on what sustainability means for them in general and specifically in Chemistry and in practice. The interviewees know they are part of a community and a field that cares for sustaining the *ecology* they are part of, and this also means that the participants are unsustainable in their usage of toxic substrates, e.g. solvents, in their tinkering, in their creation of waste, and pollution through trying out things or following known experimental steps. As one participant says:

> "there is always a factor of non-sustainability in chemistry because you have to try out so many different things" (Record 3_2, Pos. 5)

Further another interviewee said:

> "there is sometimes maybe even a second round where one tries this then again" (translated, Record 4, Pos.106).

They are *dissenting-within* their situatedness in Sustainable Chemistry through self-critical reflection on their unsustainable practices. At the same time, these "cuts" of caring relations with sustainability in their practices are necessary to develop processes that are possibly more sustainable (Puig de la Bellacasa, 2011, p. 97). Another participant puts it this way:

> "the way to the goal goes sometimes in the first step over one using unsustainable chemicals […] one needs often solvents, which are very toxic and yes, not very sustainable so-to-say in the classical sense and we use them to develop something" (translated, Record 4, Pos.106).

The researchers care-for a "goal" of sustainable practice, which needs, at the same time, practices that are *dissenting* from care for sustainability. This is also highlighted by another interviewee also using the term "goal":

> "I wanted to work on a sustainability issue, and I am doing that and I know that it can't be like as I mentioned sustainable all the time, it's research you have to sometimes use a liter of solvent but its towards a goal to not have to do that (Record 3_2, Pos. 28)"

They acknowledge that "it's research", and this conflict of being unsustainable in parts for caring for a sustainable research goal exists. They accept waste, toxicity, sometimes limited resourcefulness, and pollution as part of research practice. However, it is, as this participant mentions later, "more sustainable than what is the state of the art" (Record 3_2, Pos.30). They accept this *dissenting-within* care by comparing their chemical practice with other and past practices and thereby contextualizing it:

> "if it's a little better than what is done before I can live with that" (Record 3_2, Pos. 30)

In all, the consequence of the awareness of unsustainable practices within sustainable chemistry (*dissenting-within)* is the effort of a "constant questioning" of practices within that research that leads to change, as the PI formulates:

> "so it's a constant questioning of the things that you do in a way because you are used to do that, also of the resources that you use in terms of one-way packaging and so on... there is a lot that can be improved" (Record 2, Pos. 82)

Another interviewee similarly mentioned this, saying that they "try to change or improve things in the sense that less toxic chemicals are used or just to improve the processes" (translated, Record 4, pos 78). The last statement on improving and changing the process is combined with highlighting that they:

> "still need consumables and laboratory infrastructure, […] and it is certainly not resource-saving, it would be more resource-saving to operate practically no laboratory at first**"** (translated, Record 4, pos 78).

This statement on the resourcefulness of laboratories in general leads to my next section on *dissenting-within* practices because of conflicting relations between general academic laboratory practice in chemistry and the field of Green/sustainable Chemistry.

6.1.2.2. Dissenting-Within Laboratory Chemical Practice

In this section, I will look at caring practices that involve *dissenting* with sustainability because of the role of "classical" chemistry and vice versa.

Chemical practice in the form of resourceful laboratory work, in general, is, as explained by one researcher, needed for "our modern normal life" (translated, Record 4, pos 80), which involves "cuts" of caring relations for sustainability aspects (Puig de la Bellacasa, 2011, p. 97). Working in this area is caring for sustainability AND other relations, such as the societal functions of academic chemistry. For instance, this interviewee later in the interview names the function of their end products as being further synthesized into pharmaceutical medicine, fulfilling another type of care for a set of groups who have access to medical care[1] (Alencar Albuquerque et al., 2016; Fidler, 2010; Lakoff, 2017; Medicins sans frontieres, 2023). Sometimes, these different entanglements of the research (being sustainable, experimenting with conditions, and producing "modern normal life" products) demand "cuts" (Puig de la Bellacasa, 2011, p. 97) on different sides to be maintained. If there were no lab, it would be best regarding the demand of saving resources, as the participant notices, but the practices are needed for the demands of our "modern, normal" way of living. Here, in hindsight I would have wished to ask back what they mean by this "modern, normal" way of living, probably in that moment assuming what they meant (pharmaceutical medicine, plastic products, consumerism). Later in the interview, the participant says:

> "Chemistry in itself is probably not very sustainable in general" (translated, Record 4, Pos 102)

This brings me to my next point of discussing *dissenting* with some sustainable chemical practices and habits. This dissenting-within additionally has an image aspect for the PI, as they want to change:

> "the image of chemistry back from those that are perceived in the society as the troublemakers; as the bad guys; as the ones polluting the environment […] that are creating damage to the guys or the field that is finding solutions for today's problems" (Record 2, Pos. 67-68).

[1] Note: not everyone has access to pharmaceutical medicine making this product benefitting only selectively and unjust accessible to a group of people, because of costs, research gaps & biases, availability (Stolbrink et al., 2022), discriminatory structures (Tsai & Kesselheim, 2020), whereas the negative impacts of chemical pollution due to the synthetizing processes of the substrates for pharmaceutical medicine and affect unjustly groups of people who are already vulnerable to less access to medical care. It shows benefits and harm is unjustly distributed.

They define sustainability as “the opportunity” to achieve this. Their definition is negatively related to an image Chemistry[2] should not have anymore and positively to an image they should attempt to foster. This image-change is for them about research/synthesizing practices through their already produced knowledge (“we have the know-how […] to use CO2; how to store energy”) and their capacities to “find and provide solutions to the problems that we have today.” They state, “we can find solutions for the largest problems that we have these days even if they are probably created by chemistry” (Record 2, Pos. 67-68), also again acknowledging not only the lousy perception but the actual damaging effect chemistry had (Papadopoulos, 2022).

Further, the participant who mentioned that “Chemistry in itself is probably not very sustainable in general” mentioned another deviating aspect of their work in the same answer. Their practice in the laboratory *dissents* from other work within the scientific community because of the “practical relevance” for sustainability issues in contrast to “projects in chemistry in general where you somehow find a molecule, manufacture it only so that it is produced” (translated, Record 4, Pos.102). Both kinds of research practices relate in some ways to producing pollution and waste and are potentially damaging to the planet. The difference is that their lab relates to “basic research” with a sustainable “application.” At the same time, they cut relations to a chemical practice solely based on the idea of conducting research mainly for the purpose of research itself and “in the foreground for more complex molecules” (translated, Record 4, Pos.112).

In sum, participants acknowledge the non-sustainability/toxicity of chemical practice due to historical continuity, experimental purposes, the goal of being more sustainable, and the need for anthropochemicals for survival (Papadopoulos, 2022) and our “modern normal life.” Being aware of this, they, on the other hand, start to change things, negotiate the different “cuts” (Puig de la Bellacasa, 2011, p. 97), and *dissent* with previous/other chemical laboratory practices.

[2] With Chemistry I assume they mean a field mostly shaped by industries and institutions since the last few centuries

6.1.2.3. *Dissenting* with Output-Pressure *within* Academic Structures

In this section, I want to focus on *dissenting* from structures of pressure towards publishing and obtaining results in research *within* academia. Answering the question about what they care for in the group, the PI focuses on a positive working atmosphere in the group:

> "I like or hope that I can provide a creative environment for my students where they can work driven by their curiosity that arises from the topic, that they are motivated by the issue that's behind […] this research and by the curiosity to solve these issues and that they actively enjoy working on these topics rather than having an environment of academic pressure and publication counts in mind, which also is a topic for us in chemistry producing output and struggling through a PhD so that is something that I would care a lot that that would be possible" (Record 2, Pos. 99-100)

As this statement puts it, to care for this "creative environment" means *dissenting* with the increasing pressure of output *within* academia. This is also mirrored in literature (Burrows, 2012; Haven et al., 2019; Mertkan et al., 2022). The PI's caring-for/*thinking-for* their students' practice is simultaneously a *dissenting-within* practice, showing the overlapping of this different operationalization of care. They acknowledge it "is a topic for us in chemistry producing output and struggling through a PhD" (Record 2, Pos. 100). The statement of the PI resonates with the participating PhD students talking about the challenges of writing a PhD thesis and on the other hand the feeling that the PI is supportive towards them. According to studies, the relationship between PhD students and their supervisor is relevant to the student's well-being (Dericks et al., 2019; Wollast et al., 2023). In this lab, as one participant formulates, "working with [name of the PI] makes life a little easier because [this PI] gives you the freedom to try out the things you find interesting," giving the example of regular group meetings and input (Record 3_2, Pos. 20). This feeling of "freedom" was repeated by another lab member in a conversation during my ethnographic lab participation speaking about "how much freedom they receive in choosing their research interest and methods" (fieldnotes_2, Pos. 34). As one interviewee later says, the experience of doing a PhD, in general, can make you "happy" or can be "frustrating," e.g. "if nothing works" (Record 3_2, Pos. 46). Another PhD student similarly names as a challenge this last step to finish up their PhD thesis, highlighting that there is really a lot to do right now to finish" (translated, Record 1, Pos. 58). However, as the statements from before display, they feel support from the supervisor.

Considering the following description of the experience of the PI, the aspect of a research outcome is not so strongly tied to an economic "requirement."

> "I can do research without immediately thinking of the financial implementation, so I do not need compared to any company to make immediately money from that. I am free to research whatever interests me […], and I have the luxury that I can research that without the requirement to make it financial viable in the beginning […], that is a very privileged situation in the field of sustainable chemistry that we can do this here .. and have the vision of changing something but without the pressure that you would have in the company" (Record 2, Pos. 76)

In this statement, the PI also disagrees with working "in the company" within regular (industrial) chemical practices as they "can research that without the requirement to make it financially viable." This aspect of the category of *dissenting-within* will be discussed in more detail.

6.1.2.4. Dissenting-within Green/sustainable Chemistry Through Maturing Collectively

This section will discuss the *dissenting* practices regarding caring relations of sustainable chemistry *within* the Green/sustainable Chemistry community over the last few years. The PI mentions a collective development of *dissenting* with certain not "mature" practices and relations to their research *within* the field:

> "the field is maturing or people are growing up, there is certainly a large interest that's still growing and the importance and the recognition is constantly rising, the field is a hot topic and people are doing a lot, but people are also getting aware that you have to be careful with the word sustainable or green chemistry, especially in green chemistry in quite some time it was very popular to label your research as green chemistry without questioning too much, so I think there is a certain maturity coming to the field […] that this is not something in the end that you can do on your own but that needs feedback from other disciplines as well or proper calculations proper assessment in a complexity that it often cannot be done by a single research group on their own" (Record 2, Pos. 20)

They explain how "research [was labeled] as green chemistry without questioning too much." I associate this practice with Greenwashing in the corporate world, a marketing practice by companies to advertise with "Green"/"Sustainable" labels for certain features and hide other more significant unsustainable issues (Alonso-Calero et al., 2022). In order "to be careful with the word sustainable", these "cuts" of the too-loose relations to the "Green" label fostered new connections that acknowledge the "complexity" of Green/sustainable Chemistry (Puig de la Bellacasa, 2011, p. 97). In this maturing process, researchers developed tighter relationships in their practice as well with the surrounding scientific community to address the "complexity

of the field". This need for connection is also because "proper calculations, proper assessment in a complexity" are required. Besides the point of the scientific ideal of "proper calculations," the relevance of interrelatedness between "disciplines" and different research groups is expressed as important for meaningful knowledge practice towards the "complexity." The importance of connections will be further discussed in the section on *Thinking-with*.

6.1.2.5. *Dissenting-Within* in Conclusion

In this section, I analyzed how the researcher *dissents* from different structures and caring relations to strengthen other caring practices. First, I discussed the difficulties of working towards change in chemical practice and a vision of more sustainability while being limited to non-sustainable practices in some ways. Then, I looked at conflicted caring relations between the historically grown field of laboratory chemistry and the new Green/sustainable Chemistry field. Laboratory chemical practice, in general, allows for caring relations towards necessities in our modern life (e.g., medicine) but dissents from sustainable practices. In contrast, the new Green/sustainable Chemistry field strives to *dissent* from unsustainable practices that cause planetary damage. Thirdly, I addressed the PI's focus on *dissenting* with output pressure, caused otherwise by publishing culture in chemical science communities and affecting PhD students. Additionally, the PI highlights less financial pressure for results in their current state. Lastly, I highlighted *dissenting* practices through development *within* the community over time towards taking the complexity of the challenges of Green/sustainable Chemistry more seriously. In the next section on *thinking-with,* I will focus on *caring* relations connected to collectiveness.

6.1.3. Thinking-With

Puig de la Bellacasa proposed this category in the terminology of *matters of care* (2012), which is reflected in my data as moments in my observation of actor connections and where participants reflect upon their situatedness and relations. These hint towards interrelatedness within different assemblages of actors, relations, and practices (e.g., the Green/sustainable Community), their more-than-interest-based relationships towards themselves and others, as well as reflections about ethic-political implications. I will start with more personal relationships, including friendships and the relationship with oneself, then move to collectiveness in general, focusing afterward on connections in the laboratory and between locally close laboratories. Lastly, I will discuss community sites of scientific exchange, like journals and conferences, that connect multiple researchers and research groups.

6.1.3.1. Personal Relatedness

Starting with their personal caring relationships in this section, interviewees highlighted the importance of friendships and togetherness as factors for their work in several parts. For instance, one participant named having friendships with people locally close and who "are also doing their PhDs in different research groups" in the chemical field a privilege. This is due to their academic situatedness of studying on this campus for longer, sustaining long-term friendships in contrast to PhD students who came freshly to this locality. Different from childhood friends, these long-term friends have, at the same time, a better understanding of their situation and experiences. This kind of specific interrelation between them and other researchers on this Campus leaves the possibility to talk about un/pleasant emotions, experiences, and thoughts of various kinds. It adds a certain quality to their everyday life, which they are "quite happy about".

> "So, if I'm at a place where I am really frustrated or when I am also very happy because something worked which proves my points, then I always have people around me that I fully trust and that I can kind of do little celebrations with or "sudern[3]" which like complain about nothing working […] and I can always be like: 'hey! I need you right now, I need to let off some steam' or 'hey, this works'" (Record 3_2, pos. 46)

Thinking - through talking and exchanging with others - about work, frustration, successes, and more can, as I argue, be a form of self-care, care for togetherness and being cared for. Hence, what is described are practices of care that show that chemistry research is

[3] Austrian for complaining

not a solitary activity and that friendships/caring relationships are resources and are perceived as such ("privilege"). Further, it shows that the quality of relationships matters and is dependent on individual and structural situatedness, like where you studied before, how your support system is structured, or what institutional structures proactively/passively offer for community/network building.

This example underlines that *thinking-with* is a practice that comes with *living-with,* e.g., the situatedness in academic structures and having to make future career decisions. *Thinking* and *living-with* the position of being a PhD student, which includes caring for their research and their future career steps, was highlighted by one participant in their decision-making:

> "Of course, it affects me. At the moment, there are still a lot of directions open to me, so to speak, but that's now a very honest answer. I have to sort out a lot in myself, so to speak, that I say, yes, I want to go exactly in that direction now, because there is really a lot to do right now to finish […] and, um, yes, I'm already curious where the next step will take me" (translated, Record 1, Pos. 58)

They must "sort" in themselves, which is talking about their own inner relations - *living-with* institutional structures and expectations influences *thinking within* themselves when they care about future steps. There are options and "directions open to" them, but it is also about their individual preferences, where they "want to go exactly", which needs care work of arranging thoughts. With this unfinished yet, they can only be "curious where the next step will take" them. The outside/inside barriers of one's mind in decision-making get blurred in this example of interrelatedness and *living-with* care. This interviewee later shares how their experiences in general affected them:

> "for me personally, it has definitely brought me a lot in terms of self-confidence and appearance and how I simply live my life (Record 1, Pos. 87-88)."

So not only in their decision-making for the future but also in terms of their life in the now, their work and outside relations are connected to their inside relations. One's own feelings and intimate inner relations are part of the everyday work in the lab, as I also observed in my ethnographic practices. For instance, this passage from my field notes is about uncertainty, self-reflection, how they relate to themselves (doing their own thing), and how they move forward:

> "One time, we talked about how they, in general, feel when going through their laboratory working day. tells me there are sometimes insecure feelings. They do not always know what will happen next or what to do next. They make, in general, "their own thing" and try always to have a plan. The day in the lab is full of new beginnings/

> fresh starts, constantly asking yourself under which conditions you start your next laboratory practice?" (fieldnotes_2, Pos. 18-19)

This self-reflection in connection with one's embodiment is reflected in an interview as well, where the researcher states how:

> "It's always nice to have like a sketch of what I want to do and what path I am following and then of course it goes into different directions, but I can always come back, have a deep breath, and like try to organize everything mental[ly]" (Record 3_2, Pos. 54)

Taking "a breath, "being "insecure, " sort[ing]" oneself, and growing "in terms of self-confidence and appearance" are all indicators of how practices in the laboratory are related to one's feelings, body, and thoughts. Working in this lab involves personal relatedness; it is *thinking-with* oneself, with the body, and with feelings.

6.1.3.2. Context and Collectiveness

In this section, I will analyze *thinking* and *caring-with* relations outside personal ones. *Thinking-with,* in general, emphasizes the collectiveness of knowledge practices which is highlighted by one PhD student who compared sustainable research to a pyramid scheme:

> "When I am finished, someone else will take what I have done and will be like: 'okay I will do take that and do something that is a little more sustainable'. It's a little like a circle, like you take what other people have done and you put your own spin on it and then someone will take your work and put their own spin on it. It's like a pyramid scheme like it just goes out and somehow, I hope that at some point we'll be at a point where it won't be necessary that sustainability is a big issue" (Record 3_2, Pos.32)

A pyramid scheme is defined as "a way of deceiving investors […] in which money that a company receives from new customers is not invested to their advantage but is used instead to pay debts owed to existing customers" (Cambridge Dictionary, 2024). This does not seem to have much to do with Chemistry and any constructive form of practice. However, the comparison makes sense regarding the aspect that a scheme relies on someone starting it and recruiting other actors, who recruit themselves actors for a promise of success. There is, of course, in this case, no paying back or fees or any other form of business model involved. This metaphor of a pyramid scheme hints at how inter-connectedness between researchers

and progress (“a little more sustainable like a circle”) is related. Both metaphors of pyramid scheme and circle highlight the connectedness of different researchers as actors who can only work together to create something that will help to make sustainability, not an issue anymore. The inter-connectedness in research and progress is then related to time, as it is described in this first statement already metaphorically and later literally as a “step-by-step process towards that action that we want” (Record 3_2, Pos. 33-36)–yet not necessarily unilinear-/dimensional as the metaphors are describing circular and pyramidic processes. They acknowledge that when they add their “little part,” it can work or it may not “lead to anything,” which is also “fine, because then we know it does not work, and then someone can take that and does not need to repeat it or try something else to maybe make it work” (Record 3_2, Pos. 33-36). This process is not linear; it can “take some turns that go into a different direction,” highlighting that “it is still better than doing nothing.”

As I discussed above, these connections and interdependencies underline that the issue's complexity cannot be solved individually or by one research group but needs a collective effort, a *thinking-with* effort. Hence, I want to dive more into the immediate social work environment of the participants in their lab and between other labs on the same campus. After that, I will widen the focus on the general green chemistry community and finish with a perspective on conflicting or delineating relationships.

6.1.3.3. In the Lab and In-Between Other Labs

In this section, I describe a *thinking-with* practice embedded in collectiveness: the relations between lab researchers within the group and with other groups. During interviews, I came across a very supportive and positive feeling within the research group. One participant talks about “a very good atmosphere” with “a very strong team spirit,” where they help each other out in questions acknowledging “that everyone is better in a different part” (translated, Record 1, pos. 86). The PI answers my question about how they “experience working […] in this research group” and that they are “happy with the way the group is running right now because the team is interacting extremely well” (Record 2, Pos. 93-94). These citations highlight practices of *thinking-with* each other to produce knowledge with everyone having different resources in this lab group. Another participant brought up in a conversation during my ethnographic participation in the lab as an observer that “they can exchange” in weekly presentations about the organization and their projects within the group, hinting at a genuine acknowledgment of the other group members’ work. They add that this is what makes the lab “special” since “they can do different things” (fieldnotes_2, Pos. 34). Music can also be part of the laboratory's internal connections with each other in their chemical practices, as I noticed in

my participatory observations. As one participant explained, they cannot have headphones on for safety reasons and must decide on music collectively. During one of my lab visits, we talked about former university experiences, where different labs had different music tastes. For instance, one lab only played metal music. They add: “People find each other who fit together” and “they as well fit together,” linking music taste to the relationships between the researchers of their current group (fieldnotes_2, Pos. 30).

Further, in my lab visits, I could witness how these caring relations of sharing and exchanging resources and knowledge extended beyond the boundaries of the laboratory group. On my first day following a researcher in their routine, they had to use a machine from a collaborating group, which was in a building next door. When we arrived at the lab, it became clear that another researcher from this collaborating group was working with it over the day, and there were only short time gaps in between when the device was free. This is what I wrote in my ethnographic notes on how this sharing of materials and devices took place:

> “It was interesting to me to see how quick, nice, and communicative everything goes, and how important this back and forth between rooms and people taking you to the next person is. It felt like a flow, but also a little tense situation, where M. almost decided in-between to use the machine later.” (fieldnotes_1, Pos. 53)

It shows that caring relations can inherit tensions but still be supportive. It reflects my general feelings about this. The other day, there was a respectful mutual relationship between the laboratories, as on day two in the lab, one participant highlighted that this is also the case for the relationship between the PIs in contrast to past experiences. In past laboratory structures, only the group members from the lab interacted with each other across lab group boundaries. In contrast, the PIs would request money if researchers from another lab used their machines and did not always seem to like each other. In contrast, now, the participant experiences that there are PIs who interact with mutual support without financial receivables (fieldnotes_2, Pos. 36). Regarding *thinking-with,* I further wrote on day two in the lab reflections on sharing and exchanging practices in this passage:

> “Regarding care, I see again how much these small negotiations are present and rely on the premise of mutual support between the researchers even beyond laboratory borders. The researcher tells me about how they support where it is needed, how they talk to each other, and manage smaller bottlenecks” (fieldnotes_2, Pos. 30-32)

Afterward, the participant goes on to describe in more detail how there were conversations that they had in the collaborating lab about where to find what. When I was in the lab, somebody asked where a particular chemical was, and they could give the information

to the other person. “Everyone knows who has what, and you can look if somebody has what you need in the neighboring lab.” (fieldnotes_2, Pos. 36). This again underlines how the collegial exchange of information and resources is part of their chemical knowledge practices.

Taken together, knowledge production and their day-to-day work are situated and rely on caring relations that are primarily positive and supporting towards each other with a feeling of togetherness within the group (“that the students […] are working together and not against each other”, Record 2, Pos. 94) and collaborating relations with researchers of other labs. I will discuss collaboration and community in the broader sense next.

6.1.3.4. Conferences & Collaboration

In this last section on *thinking*-with practice, I consider cooperation on a wider scheme with this and other research groups that can be but are not necessarily in the same or neighboring building and locally more distant. The PI explains in this regard that “there is a lot of cooperation ongoing, so which is also caused by just a personal liking” (Record 2, Pos. 36). This is beneficial to them not only in their knowledge production processes but also in terms of thinking with sustainability in their day-to-day practice. This is because, as I understood after a description of collaborating interactions such as meetings and conferences, they get their “inspirations through other groups and other initiatives for changing these small habits” (interviewer, Record 2, Pos. 83), which is a statement the PI confirms (“certainly”, Record 2, Pos. 84). Conferences are one central space where these connecting interactions take place as one interviewee reports, saying “you get an overview”, “you get to know more different things” and “inspiration” (translated, Record 4, Pos. 56-60). Another participant praises conferences in general and not only in the field and sense of “sustainability” talking about their …:

> “experience […] when you are among like-minded people and then just talk to each other, different experiences come together, and sometimes when you try to solve a problem in a narrow-minded way, you get a different horizon when you were abroad, when you were among colleagues […] it's definitely good and I think it also advances science” (translated, Record 1, Pos. 70).

This is a view of science and its community as a collective and exchanging effort to produce knowledge, where exchange has a positive impact. This citation also blurs the line to communities outside the Green/sustainable Chemistry field**.** Overstepping their disciplinary boundaries through collaborating scientific connections is underlined by the PI as preferable as well, saying that they “like to see what others are doing and not stay in my research area”,

mentioning further that they “like the projects most that are cooperating with people from other fields to get input that we do not have” (Record 2, Pos. 83-84). It also brings me to my next point of how communities might relate to each other.

Thinking-with is thinking about sustainable practices within a community and a context nested in other contexts, which can evoke conflicting viewpoints (“two sides”), as the following citation shows:

> "Because I'm now in this group, that I'm more in this sustainable track, you get something from this side, so I would just have to go into other areas to see what other people think about it, how they see green chemistry, sustainable chemistry in general because there are always two sides" (translated, Day 4, pos. 48)

This statement highlights the possible critiques or different perspectives from “other areas” and speaks of “two sides”. Since the first part of the sentence mentions their group and the “scientific track” they are in, I assume the “other areas” are scientific communities and groups not part of the Green/sustainable Chemistry community. This reveals the interviewee's thinking about connections to fields not internally part of the scientific community’s network and may still be related to their research. This showcases that *thinking-with* practices in research involve relations of concern and different, even contradicting, opinions (“two sides”). Overall, the statement showcases how diverse fields, groups, and communities are interrelated within the field of science–connected, overlapping, and contradicting. Moreover, the statement may also hint towards other interrelated “areas,” e.g., politics and social groups.

These different data bits show that *thinking-within, living-within,* and *caring-within* as part of a laboratory group is complex, entails multi-layered relationships, and involves reflecting on one’s situatedness (e.g., privileges, or the “track” one is on).

6.1.4. How Do Actors Practice Care in The Context of Sustainable Chemical Practices In The Laboratory?

With the previous categorization of observations, I discussed caring practices and relations through the terminology proposed by Puig de la Bellacasa (2012), which is only one way to structure them. *matters of care* such as *thinking-within, thinking-for,* and *dissenting-within* were present in my analysis of the Sustainable Chemistry Lab I am investigating. There are multiple ways in which the actors care through their practices, which are not always chemical practices but related to their everyday activities in the laboratory - like speaking to friends about achievements and disappointments. They tend to practice caring for something related but distinct to them as individuals (the environment, other groups of people). They are partially reflective of the limitedness of their practices. They see themselves as part of a lab, institutional and societal structures, and a field - caring for what they are doing and their role. The question remains do they see themselves and their practices as an integrated part of an *ecological* system or as distinct actors affecting and being affected by an "environment" (e.g., Record 2, Pos. Pos. 76 or Record 2, Pos. 67-68)? The data did not make this clear to me.

Important to notice is how participants interpreted the meaning of care when directly confronted with the questions about "what do they care for" (in the lab, in their work, in general). Mostly the interpretation was towards practices for safety and for the research process. Additionally, one participant named caring for reproducibility and precision as in correct scientific practice, and the PI named caring for an enjoyable working atmosphere. This does not exclude that the other participants did not also care about these aspects, it depends on what came to their mind when prompted with this phrasing and what they wanted to talk about. These, in addition to my interpretation of their actions and what they spoke about, show a high variety of *matters of care* practices and relations in the lab.

6.2. Green/Sustainable Chemistry

In this section, I will discuss the data regarding the theme of Green/sustainable Chemistry. This field of chemistry was, on the one hand, a present topic in the interviews, often brought up by the participants themselves as their organic chemistry lab is concerned with this field. On the other hand, Green/sustainable Chemistry was part of my literature research and preliminary interest when approaching this lab as a possible case study. Hence, in the following sections, I will address these questions: How do actors define and enact Green Chemistry in their chemical and related knowledge practices, like discussing and calculating? Which resources and properties do they consider? Which political (institutional, personal, public, historical) aspects become apparent? How do chemical pollution and toxicity–a focal point in STS literature regarding chemistry in the Anthropocene–play a role? One connecting string of my analysis is the personal viewpoints and relations to Green/sustainable Chemistry.

6.2.1. Goals and Long-Term Thinking:

In this section, I will address the application aspects of basic science approaches within their work, defined goals towards CO_2 usage, long-term thinking, and resourceful practices.

6.2.1.1. Application & Basic Research

In the following, I will highlight application goals and basic research aspects, as these are important aspects of their laboratory practices. I will focus on descriptions of both areas, their connectedness in their work, and how they are relevant to Green/sustainable Chemistry.

Basic research aspects, as the PI argues, allow for “creativity” to “try ideas and see where they would lead even though at the beginning you might not have a large-scale application in mind” (Record 2, Pos. 102). Simultaneously, “applied research […] should always be an aspect” (Record 2, Pos. 102). One PhD student highlights why application research aspects are personally relevant for them:

> “it's precisely this application that is important to me, that the product you have in your hand also makes sense” (day 4, item 26, translated)

One PhD student formulated their work as “basic research but just with a sustainable goal” (translated, Record 4, pos. 102). It means “being involved in a bit of a project with application” where they “enjoy the fact that it has such a practical reference” (translated, Record 4, pos. 102). Another student makes the example of “Marie Curie with radioactivity”,

which is in in general “the basic” about “just finding new things” in contrast to what they are doing (Record 3_2, Pos. 40). In this way both statements demarcate the lab’s projects from strictly basic research. In their research, “to bridge the […] the gap between […] academic research and actual application” is a focus, which is related to motivation, personal liking, enjoyment, and interest of the researchers and is also a “necessity”. The PI highlights this “necessity” in the context of a time where “everyone wants to commit to sustainable chemistry [but] companies probably after years of pandemic and financial struggling are uhm a bit reluctant to […] take the risk of the next step” (Record 2, Pos. 104). The connectedness in their research of both basic and application approaches was further made clear in this statement:

> “Whether this substrate I am using now is suitable for this application or another application is completely open and if there would be an application in the future, then a goal would be achieved” (translated, 4th day, pos. 46)

I think the “and” in this statement underlines how basic and applied science approaches are two areas that are not in conflict but go hand in hand in their research. This hints towards a continuous character of the relation between basic and applicable research, which is further displayed in this statement by another PhD student:

> “You have to differentiate between the basic and trying to enlarge the base and continuing to make something more sustainable” (Record 3_2, Pos. 40)

They have within their group researchers working on this continuum between the two described areas:

> “We also have […] colleagues that are trying to work on that base of chemistry side, but we also […] put a lot of focus on, well CO_2 valorization […] and kind of […] starting from different places” (Record 3_2, Pos. 40)

In sum, these statements display how the researchers are aware of a goal of application in their work, their situatedness in leaning towards basic chemistry research, and the non-binarity between these two aspects. In the following section, I will focus on application goals in the CO_2 project, followed by a short reflection on the term sustainable (=nachhaltig) itself.

6.2.1.2. CO_2/Pollution Usage And Circular Economy

Three general goals are formulated for valorizing CO2, which will be discussed in this section. First, using it as a “building block” to make petrochemistry obsolete. Second, to reduce pollution that promotes climate change, as the PI highlights, there “obviously […] is a connection between rising CO_2 levels and the atmosphere and global warming” (Record 2, pos. 12). Thirdly, to apply their research results in the future to an industrial level, as in this quote:

> “The CO_2 that is currently used is probably mostly a waste product from the petrochemical industry, and, of course, there is enough CO_2 in the air or from exhaust gases from processes that will probably not be preventable in the future, so there will always be some industries, for example the cement industry is also a very large CO_2 emitter” (translated, Record 4, pos. 38).

The translation of the CO_2 pollution issue into a solution approach, as it is described by the participants and in literature, however, is complex and needs specific practices and intermediate substances (e.g. CO) that are connected to toxicity and potential planetary harm. This is also true for the retrieval of CO_2. Even though there are numerous providers for CO_2, the PI explains that now the direct use from an “industrial plant” is not yet “realistic”, since the research is tied to “laboratory chemistry” (Record 2, Pos. 12). A vision for a future goal voiced by a PhD:

> “Dream, of course, it's a utopia at the moment, but there could be a factory where you practically switch off the CO_2 and then use it directly” (Record 4, Pos. 38-40).

I end with this citation describing a vision of the CO_2 valorization goals and will subsequently analyze a reflection on the term “nachhaltig“ and its meaning for long-term thinking.

6.2.1.3. Nachhaltig/Sustainable

One point a participant made was very interesting to me, defining in the interview "sustainable" in its literal meaning. Since the conversation was in German, it was about the word "nachhaltig," which is reflected in English (maybe with a slightly different composition, "Haltig" might be translated with "lasting," and "nach" with "after"). The participant says hence:

> "Sustainable that means it makes sense for a longer period of time and not just for a short period of time"

Which separates it from work that is not "nachhaltig," so only for a short "period of time." They further "have the feeling sustainability is also misused nowadays,"–linking to the point of Greenwashing made in section 5.1.2.4.–where research can be "nicely presented" but is not by their definition sustainable, which they illustrate with the following example:

> "if you somehow think in advance that it could work for half a year or for a year, but after 10 years, we don't really know what we will do with the waste, for example. For example, if we don't know what we're going to do with the waste that's produced by this process, then I don't think it's sustainable." (translated, Record 1, Pos. 60)

On the other hand, they acknowledge "that we can't look into the future" and that one can't hence secure know what happens in ten years. They link this inability to the imperative that "we have to start somewhere." Simultaneously, they stress that they "should take" sustainability "into account more" while being "honest with ourselves" about this inability "to start somewhere" (translated, Record 1, Pos. 60).

6.2.1.4. Resource

Lastly, I will discuss resource-saving practices before going over to political aspects and toxicity in their practices. The formulated twelve ideals of Green Chemistry practice in the laboratory are centered on avoiding chemistry *"benign by design".* One side of this is what was discussed before regarding the striving of the lab for various sustainable goals in different ways simultaneously. The other side is about the research practices and conditions in the laboratory for this goal that are in some ways unsustainable but in others more sustainable than other current chemical practices (see section 2.1.2.1&2).

One aspect of the practices mentioned by the participants was ways to be more resourceful, which I also observed when I was in the lab. In the interviews, the participants spoke about materials to reduce, like plastics and other "consumables," but also the usage of

toxic chemicals, such as solvents and gas,thereby producing less (toxic) waste, which will be discussed in section 2.2.3. Besides chemicals and other consumables, energy, substrates, money, and water are further important resources consumed in the lab, which they are aware of. For instance, in the case of the glovebox, they try to reduce energy consumption, as the device:

> "is energy-intensive […] they explain how they are using a nightmod[e] for the constant controlled flow the CO_2 gas bottles must be under. This saves energy for warmth and gas as well. (fieldnotes_2, Pos. 4-5)"

To save further substrates and money, they buy non-refined argon gas and filter it in the lab themselves (fieldnotes _2, Pos. 4-5). Water can be saved through changing practices and processes.

> "This was an incredible amount, so it was absolutely common to keep the water running days and nights because this was how you cool reaction, that's how you did it for the past 50 years and how you learned how to do it and by now we have exchanged this with an internal water recirculation system for cooling but even later now we realized we don't need that at all you can also use air ventilation for cooling" (Record 2, Pos. 82)

Also, regarding practices of traveling and dissemination of science energy can be saved up:

> "For me it was very common to fly to meetings and conferences every second week at least and often for just one day, and then we had to stop that and use video calls [pandemic times], and for now, I would never ever fly to Brussels for one day because we can do it online" (Record 2, Pos. 82)

Reflection, asking questions, and communicating were named as practices for sustainable change. In this case, a non-controllable factor (pandemic) has forced other forms of disseminating science and thereby gave the impulse to re-think the previous traveling practices. This shows the acknowledgment of the interweavement of diverse knowledge practices (from tinkering and saving resources to questioning and communicating) for a transition towards laboratory research work that is more sustainable and less resource-intensive.

6.2.2. Political Aspects

In this section on the theme of Green/sustainable Chemistry, I want to illuminate the political aspects derived from the conversations and observations I made during the laboratory visits and interviews. These include the reflection of power over decision-making, effects, and limitations in the actions of the participants as well as other political actors, which are the communities, institutions, and financial investors.

6.2.2.1. Participants Reflecting on Their Situatedness

A question posed by Papadopoulos (2021) makes the political dimension of chemical practices explicit about the benefits and harms of laboratory researchers:

> "Who has the freedom to decide what chemical substances to create and at what cost, and how is this freedom achieved?"

… which relates to a question in one of the participants' reflections:

> "I think it is always, like, its more sustainable than other things … of course, like who decides what is sustainable?" (Record 3_2, Pos. 5)

Here, the participant points to the freedom of decision-making not over "what […] to create and at what cost" (Papadopoulos, 2021) but more essentially over "what is sustainable", thereby influencing chemical practice. Further, they say, "Everyone is doing their own part" and attempting:

> "... and I guess for me it's like a more sustainable way of trying of doing things. […] In science and research, it's always a trial-and-error thing, but the overall goal is to have a more sustainable way to live I guess? and I think it's also so everyone that is working in an area that is towards a more sustainable future is doing their own part. So, is it sustainable? I think […] you can discuss that with philosophers… it's just in my opinion it's... I'm or our research group is trying our best to take what we have and make it more sustainable." (Record 3_2, Pos. 5)

They, as researchers, are not in the power of decision-making on defining the most sustainable way of creating at less cost. Only philosophers might be able to discuss this on a fundamental level as they stress. Their approach is not committing to certain chemical practices but about trying these out.

In another conversation with the PI, the awareness of their research practices' implications beyond the borders of the laboratory was brought up when they spoke about one application

of their projects: “reuse and recycling of […] metals”. This knowledge production - creating new processes–could change current circumstances. They spoke about the issue of mining, globally buying and importing the raw materials needed for batteries in e-cars for instance. Therefore, they connect their practices and research goals directly to geopolitical issues.

Further, a transition away from the petrochemical industry through their influence was important to the participants, too. The lab group aims to implement the usage of bioderived products and pollution-based CO_2 starting materials to produce, for instance, plastics and medications. Bioderived, as explained to me by the participants, describes substrates from “natural” products. In their case, these are plant-based food wastes, like orange and apple peels. The researchers' long-term goal is to change industrial and research structures from the ground up by replacing petrochemical practices (Avasthi et al., 2023; Demiralay & Yilmaz, 2023). However, as indicated by the participants, this change of doing is a step-by-step process and their research is “one step that we can take” (translated, Tag 4., Pos.44). It is “only a first step” to “produce chemicals from existing, i.e. greener building blocks, […], that at some point you will need less petrochemicals” (Record 3_2, pos. 32). They can realize through CO_2-derived chemical replacements of “most of the products that are currently made, that are based on petrochemical starting materials”. However, this is in the “laboratory phase still” as the PI formulates and does not apply to industrial production (Record 2, Pos. 16).

In this regard, I want to highlight again how political thinking is also influenced by reflections on the limitedness of the chemical practice and its effects. According to the participants, no institutionalized chemistry is in all aspects sustainable–at least not yet–but only an attempt to be more sustainable than previous or other practices. This statement is reflected by the text by Sheldon (2008) which argues for “the words ‘greener’ and ‘more sustainable’ rather than ‘green’ and ‘sustainable’ because there are many shades of green as well as degrees of sustainability.” (p. 359). This shows that the political agenda of Green/sustainable Chemistry includes (Sheldon, 2008; interview data) reflectiveness towards achieving their goal of sustainability. The following piece of interview data displays a self-aware approach:

> Interviewer: "Why is it a sustainable project for you?”
> Interviewee**: “**I'll put it this way: We **certainly can't save the world with the project**.
> That would be a bit too high" (translated, Record 1, Pos. 43)

The participants talk about their uncertainty in research, the potential negative impacts of their chemical practices, and their step-by-step and trial-and-error process. They make clear that they are more sustainable but not sustainable in general. In sum, the participants' personal stance gives insights into how to understand the sustainable chemistry communities’ self-assessment.

6.2.2.2. Outside/Inside Green Chemistry Politics: Awareness, Debates & Political Actors

In this section, I will briefly summarize different political actors that became apparent in the interviews: community, institutions, and financial actors. The latter will be discussed in more detail in the next section. One political actor spoken about is the scientific community, not only consisting of the Green/sustainable Chemistry community (which is, of course, also not strictly separatable, homogenous, and containable). In one reference, the participant mentions how the field of Green/sustainable Chemistry is a “hot topic”. This shows its political relevance to the community, yet they add that they are biased given this phenomenon (translated, pos. 48, Tag 4). The community aspect is analyzed in more detail in section 6.1.3.2-4, but here, I wanted to make the point that it is also a political factor. Communities influence each other in various ways and are influenced by the situatedness of their members and current political circumstances (like policies, investment interests, alliances, etc.).

Other political actors in research are institutes, as they give structure and are shaped by historical continuities, policies, and societal context. When I asked how institutional context influenced them, the answers were rather short and highlighted the positive sides. One PhD student talked about the academic requirements for credit points in addition to working on the thesis which are rather low and not strongly impacting their work. Students praised the good infrastructure and the support, mentioning that the new master’s program might bring more attention to them, which might open the possibility for more interested students as well (translated, Record 4, Pos. 68). This implies that building a particular institutional structure can have beneficial influence and can therefore be interpreted as having a political dimension as well. The supervisor spoke, as in the chapter SOA already cited, about the general academic pressure in research, but this was not specific to this institute. Another type of political actor that is connected to their research and was brought up by the interviewees is financial actors. They will be discussed in the next section.

6.2.2.3. Financial Actors

In this section, I will summarize the role and interaction of financial actors and aspects of the laboratory. Financing academic Green/sustainable Chemistry projects is a topic in the interviews. Laboratory work is costly. Investing actors and their relations to the laboratory are political: They are influenced by and influence regulations, governmental incentives, debates, local economic interests, and general power balances. Reflecting on this, participants speak about the interrelations between financial actors, research, and outside/inside politico-economic factors. In one comment, for instance, the PI speaks about the "financial struggling" that makes the "companies reluctant" concerning sustainable chemistry (Record 2, Pos. 104). This affects their viewpoint on how to make their research more approachable and connected to the industrial field (Record 2, Pos. 104). On the other hand, they stressed in the interview that they have certain flexibility due to the large European Research Council (ERC) grant. It also shows a certain self-distinction between their lab, having more favorable financial conditions, to the general field. The influence of the ERC grand makes the EU governmental bodies a political actor, as with this tool, they bring together financial resources for research and interest in sustainable technological solutions because of geopolitical issues of planetary damage. The PI speaks about this EU level, where "sustainable chemistry certainly is an issue where you would get funding for these topics" (Record 2, Pos. 28). In contrast, for the Austrian national government, the "criteria" of sustainability are not needed for the acquisition of funding for organic chemistry projects like those that the lab is focusing on. There is no "direct impact" through this new geopolitical focus on sustainable technoscientific developments. However, as the interviewee brings up:

> "it is certainly in an indirect way affecting funding and awareness because there is the […] interest also with the referees, and it's easier to get funding for [a] topic that is attractive, that can be easily understood, and that is a topic where everyone immediately recognizes the importance" (Record 2, Pos. 28).

The influential relationship between funding and research is further exemplified by the shared experience of one participating PhD student. They didn't get funding from another group for their doctoral thesis and, therefore, searched for a new group. This participant chose this group, which had sufficient financial resources to employ them as a Ph.D. student also thanks to the ERC grant (translated, Record 4, pos. 2). This general presence of different financial actors influencing the field of Green/sustainable Chemistry is similarly reflected in statements of the PhD students. They are perceiving an increase in "money being invested" (translated, Day 4, pos. 50) and "how more and more projects are being started and more students are working on the subject" (translated, translated, Record 4, pos.66). One participant explains it with "simply a need to do something and to find alternatives" (translated, Day 4, pos.

50). This again makes a relation between research funding and planetary damage that are tried to be cared for through technoscientific solutions. One participant - by beforehand mentioning that this is a political point they are making - interprets this financial relationship as an indicator of the perceived value of their work. In this context, I interpret the value mentioned as more than just monetary but socio-political. They argue for this link between societal topics and funding research as they say that:

> “Investors […] know that sustainability is a big issue nowadays, so they want to fund projects […] working on a sustainability issue […] I guess if you add sustainable also to your research proposals, chances are higher” (Record 3_2, Pos. 7-8)

This further connects these political and financial relations with pragmatic decision-making on how to argue in your project proposal when working in the chemical field (Record 3_2, Pos. 7-8).

6.2.2.4. Conclusion on Political Aspects

In this section, I have analyzed and summarized the political aspects of my data. In the first part, I discussed the participants' political situatedness in their work, including their decision-making, their reflectiveness, and their limitedness in what they were doing. In the second part, I illuminated further political actors, such as their communities, institutional structures, and financial actors.

6.2.3. Toxicity

In the last topic of the theme of Green/sustainable Chemistry, I want to discuss toxicity in the lab and related infrastructure considerations. I will further elaborate on perspectives on pollution, purity, and waste practices in the lab. Toxic chemical pollution is a topic that comes up in the ethnographic fieldwork without explicitly prompting questions from me, which indicates the prominence of this topic in (Green/sustainable) chemical practice. In the conversations, different gases and solvents and their toxicity and the reasons to use them are explained to me, so it is an issue closely connected to their day-to-day actions and reflected by them. In this section, I will shortly discuss the toxic substrates Dimethylformamide (DMF), methane, nickel, argon, and carbon monoxide and how they relate to their work. Afterward, I will discuss infrastructure and practices, followed by a section on waste, and conclude with a reflection on non-polluted worlds.

6.2.3.1. Toxic Substances

In their research, toxic solvents are used for reactions–in one case for a reaction imitating photosynthesis to produce carbon monoxide. This is a fieldnote on the second day of ethnographic observation that describes this experiment:

> They are telling me that the DMF [Dimethylformamide], which is the solvent of this reaction, is "environmentally" (umwelttechnisch) not good. That's why the researcher is trying in other experiments through changed conditions to use other solvents. (fieldnotes _2, Pos. 7)

This paragraph shows the step-by-step way of being more sustainable than before. The ideal for them would be to avoid using toxic solvents at all. Using non-toxic solvents such as water in the reaction doesn't mean they can avoid producing pollutants in total in the process. I ask about methane–which is also a product in these experiments - because normally it is seen as a pollutant that is also part of the greenhouse effect. However, they say it is always just in a minimal dosage (fieldnotes _2, Pos. 15). Here, a minimal dosage is accepted, underlining that pollution cannot be avoided in total because it is, as cited before, a "less toxic pollutant" and arises through processes in organisms. In total, this shows that pollution is not something one can always avoid, but one can find ways to reduce it or its toxicity.

Argon - in line with the researcher's viewpoints on practice that is not sustainable but more sustainable than other things–is stressed in one laboratory observatory participation as a "not so toxic" solvent, but for safety reasons, the vessel is sealed afterward (fieldnotes_1, Pos. 37)

Nickel being used in the research group as a “kind of poisonous” base for a substrate is also mentioned. Yet, they are “careful,” and it’s “a little better than what is done before” (Record 3_2, Pos. 30). Here again, the non-perfectionism and acknowledgment of little steps that are done is demonstrated, which means that a certain amount of toxic pollution is accepted.

Lastly, the participants also spoke about carbon monoxide, which is more reactive and, therefore, useful for the synthesis of complex organic molecules, which are needed for medicine production, for instance. Carbon monoxide, however, is described as “poisonous, so you shouldn't breathe it in”—making here a connection between toxicity and bodily practices probably to communicate more impressively its harmfulness (Record 3_1, Pos. 19).

Because of the diverse toxic substrates they work with, the lab’s infrastructure and research practices play a role in ensuring safety and sustainability, which I will discuss in the next section.

6.2.3.2. Infrastructure and Practices for Safety Regarding Toxicity

Their laboratory is also structured by the factor of toxicity. For instance, as it was explained to me on day one of visiting the laboratory for data collection, there is a separate smaller room which is the more toxic area that has also more water connections and where every workbench is shielded–which are both infrastructure characteristics for safety (fieldnotes_1, Pos. 13). Regarding practices of caring in the laboratory, these are mainly associated with safety practices:

> “all the times I am working with like very toxic chemicals, and I have to be very careful, and I guess yeah… in the lab, I also have to take care to know where what safety issue is happening” (Record 3_2, Pos. 54)

It points not only to securing practices like using gloves, separating waste, having shields and specific clothing, and using as few toxic substrates as possible in the least possible amount but also to the importance of gaining knowledge of circumstances and situations and how to react to them. In the next section, I want to focus on related waste practices.

6.2.3.3. Waste in Their Everyday Work

In this section, I will focus on a topic related to pollution, which is often pollution itself: waste. Industrial and academic chemistry in the past and now is an actor that "created waste" (Record 2, Pos. 10). In the lab, I observed different cleanup and waste activities. Considering care practices for waste, is relevant for the researchers as they tell of their day-to-day practices of "not dumping too much material, so syringes, gloves, and paper hats" (translated, Record 4, Pos. 136) and being mindful of "the resources that you use in terms of [single-use] packaging and so one" (Record 2, Pos. 82).

On the other side, waste is also brought up as a resource–something that can be reused. In the case of the lab's work, CO_2[4] and bioderived substances could be seen as such valued entities. The PI mentions here their involvement in the topic of waste:

> "Just by coincidence, like two large projects on recycling that I found very interesting, and since then, I've been moving in this field of sustainable chemistry. Anything that is involved with waste valorization or recycling or carbon dioxide usage, avoiding toxic chemicals, and so on and that then became the focus of the research. Also, because it's a topic that fits well in the time" (Record 2, Pos. 8)

Ultimately, different arguments for waste practices were voiced, like that bioderived substrates might be less toxic and that recycling is a question of current time.

Regarding avoiding unwanted, non-reusable waste - like toxic substrates - they underline the difficulties in practice and the need to accept a certain amount. Interviewees are saying it is "expandable" (translated, Record 4, Pos. 136), there is "a lot that can be improved" (Record 2, Pos. 82), and that creating waste is needed for other aspects of caring such as safety. Regarding the latter, I described the following in my ethnographic observations:

> One thing that we talked about is that they try not to use the plastic gloves all the time, because you can partly do the work of picking things up with tweezers, but for safety reasons and for the reagents/reactants to not get contaminated you need to use gloves. So, it's a trade-off of different devices to hold things. (fieldnotes_1, Pos. 19)

This trade-off metaphor in saving up waste while being safe again shows the role of *dissenting-within* a network with certain relations for other relations to be fostered. In another interview, the aspect of the nature of scientific research about how it is necessary to produce waste is also mentioned:

[4] As one student guesses "the CO_2 that is currently used is probably mostly a waste product from the petrochemical industry" (translated, 2.intake, item 38)

> “Especially in research, if we don't know we have new processes, no [new] optimized processes for example, we probably generate more waste, whether and how this can change in the future is questionable.” (4th day, pos. 64)

In this section, I summarized the researchers' waste practices. In the last section, I will explore the researchers' entanglement with toxicity. How are the viewpoints and practices of the participants in this case related?

6.2.3.4. Non-Polluted World(s)?

In a conversation with the PI, I prompted the topic of pollution and toxicity by asking about the “zero-pollution ambition”, which is part of the EU’s Green New Deal’s “chemical strategy” (European Commission, 2020b).

> **“**Ambition is a good term. It’s important to have ambitions, and I like challenges and uhhm and any step. It’s certainly something where we are not there yet ... A CO2-free chemical industry, that’s still a huge step to go, but I also think step by step it would be possible, or it is possible to go there and uh well ideally you would have a chemical industry that is based on carbon dioxide, hydrogen, biomass, and waste plastics as as the four starting materials rather than uhm petrobased chemicals. So, in terms of expertise and chemical know-how I think it’s possible and it’s certainly good to have this ambition ... in terms of realization it will of course still take some and especially the implementation on larger scale in industries” (Record 2, Pos. 63-64)

In this citation, they don’t oppose the possibility of a zero-pollution, toxic-free environment, which contrasts with STS literature on *ecology* that is never “pure” (Shotwell, 2016). However, the PI stresses that this is not the reality of now, and it would further require steps through “expertise and chemical know-how” to get there. I prompted this answer by asking about this specific wording, whereas in the interviews no one spoke of the goal or vision of an *ecology* without toxic chemical pollution. I would argue, therefore, to not interpret it as being unrealistic and not aware of the all-encompassing toxicity but as a sign that there is no total opposition to this ideal from their academic chemical scientific perspective, which contrasts with other STS positions. In another moment in the lab, one PhD student also shows again the general awareness in academic chemical practice of the overall presence of toxicity in the laboratory:

> “Since I ask for the ‘toxic waste’, M. looks confused, maybe amused, and says everything [what they use] is toxic in theory and shows me the danger signs on the substrates. I feel

naive. There is no specific extra substrate that is specifically toxic." (fieldnotes_1, Pos. 34)

It underlines the general acknowledgment of toxicity and its all-encompassing existence. In line with the idea of *toxic politics* and *slow activism* (Liboiron et al., 2018) and what I perceived in conversations, in the lab, and also in this analysis of how they approach their chemical day-to-day practice, it makes sense to: think step-by-step, trying to be "more" sustainable instead of claiming to be already sustainable, rethinking and "question to use of toxic solvents more and more" (Record 2, Pos. 90). I think the following autoethnographic reflection stemming from my observations fits this observation:

"I try to structure these [ethnographic] impressions and illustrate it for myself as a process with different building blocks (a metaphor that also the researcher uses). These building blocks can be replaced and are constantly trying to be replaced with environmentally better building blocks. This is always a matter of considering the mutual effects these changes have. The whole process is an interplay between these building blocks and certain conditions. And on another meta-level, this is also about considering factors of security, efficiency, and sustainability which are driven by utopias, end-goals, and plans." (fieldnotes_2, Pos. 27).

6.3. Summary of the Analysis

In this analysis, I have focused on my two core themes of *matters of care* and Green/sustainable Chemistry. In the first part of *matters of care,* I described caring relations that included *thinking-for*, *dissenting-within,* and *thinking-with* practices. *Thinking-for* practices were given towards the future–envisioning a circular economy–towards an environment and others affected by safety risks and toxicity in the laboratory. *Dissenting-within* practices were presented concerning statements of the participants. The participants discussed changing and maintaining chemical practices sustainability goals in conflict with unsustainable laboratory chemical practices relevant to modern life aspects. Additionally, output pressure within academia and industry was also discussed as changes within the Green/sustainable Chemistry community toward labeling research as "green". Finally, considering the theme of care relations and practices, the data was analyzed with the category of *thinking-with.* Here, I described the role of personal relationships, friendships and those with oneself, and connections of collective collaboration–from internal lab group togetherness to conferences and journals.

In the second part of the analysis, I focused on the theme of Green/sustainable Chemistry. First, I sketched the different areas of chemical practices and goals that I recognized were important to the participants when speaking about sustainability in their work. Those included the reduction of petrochemical industries, CO_2 pollution, and waste and finding alternative ways to synthesize anthropochemicals, for instance, bioderived ones. Further, it was about aspects in the laboratory practice itself, having both application and basic chemistry aspects present their work as well as long-term thinking. After these different topical areas, I continued interpreting the political aspects of their work in Green/sustainable Chemistry. Hereby I looked at financial, institutional, and governmental actors and the political implications of their laboratory practices. Lastly, I focused on the toxicity and pollution aspects of their work, starting with describing the slow change towards using fewer toxic substances and reducing pollution and how connected safety risks are influencing their infrastructure and practice. In this last section, I focused on waste in three dimensions: as a practice, as a resource, and as an unwanted byproduct. I concluded with a reflection on the goals of non-pollution. In the next chapter, I will further develop these analytical aspects.

7. Discussion

In this chapter, I will discuss the results I analyzed and conclude by answering my research questions as comprehensively as possible. The central research question, along with its three sub-questions, is as follows:

How do actors practice care in the context of sustainable chemical practices in the laboratory?

- *How is sustainability understood and approached in the everyday laboratory and the discursive practices of the researchers?*
- *How do actors care for chemical pollution through their practices?*
- *For whom and what is (not) cared for?*

I will answer the first sub-question on how sustainability is approached and understood based on the concepts of technological determinism, transcendence, and immanence, and the political dimension of their reflections. Then, I will discuss how actors care for chemical pollution through their practices. This section will bring together two experimental entities analyzed and their chemical practices' compromising/complicit aspects. It will conclude with an outline of the dimensions of power inherent to the question of pollution care. The last question will be approached by looking at caring relations in their knowledge practices. Moreover, I discuss the mutual relations of what/for who is cared for and what/for whom is not cared for, highlighting how cutting one caring relation to something/someone can foster new caring relationships. As a final step, I will discuss the main research question through the concept of *slow activism* (Liboiron et al., 2018) conclusively bringing my previous arguments together.

7.1. How Is Sustainability Understood and Approached in the Everyday Laboratory and The Discursive Practices of the Researchers?

In this section, I will discuss how sustainability as a term and principle is understood and spoken of and how it influences the participants' day-to-day work. The answer to this question will be discussed in the following.

One aspect of understanding sustainability in the context of the participant's everyday practices is examining how and to what extent the participants' statements about sustainable practice complied with technological determinism (Wyatt, 2008). Furthermore, the dualisms of basic/applied, laboratory/field, academia/industry, etc., became apparent in this understanding and will be discussed concerning transcendence and immanence (Papadopoulos, 2022). Lastly, I will work through their political reflections on their impact on sustainability through their practices in the laboratory.

7.1.1. Technological Determinism

One specific theme I identified in the analyzed data of the participants speaking about sustainability in their practices is technological determinism, as exemplified in the quotations. This concept was explained in the theory section, and the following quote illustrates the presence of this viewpoint in the interviews:

> "We simply adapt ourselves to their requirements and hope that they continue to function in the predictable and expected ways promised by those who sold them to us. It is because technological determinism conforms with a huge majority of people's experiences that it remains the 'common sense' explanation." (Wyatt, 2004, p. 169)

To answer the first sub-question, I will analyze the participants' understanding of sustainability in terms of the application of or differentiation from technological determinism.

7.1.1.1. Goal-Oriented Technological Determinism

In this first part, I will discuss the technological deterministic tendencies I identified in the research, particularly regarding goal orientation. These tendencies contribute to understanding how participants envision sustainability as a principle and/or goal in their practices.

The participants define their chemical practices regarding sustainability through their vision of a circular economy and reuse practices by demonstrating how they "provide" "solutions" (Record 2, Pos. 70 and Pos. 67-68). In this way, they apply a technoscientific approach in their day-to-day practices, which is goal-oriented, linear, and includes means-to-end thinking. In the interviews, the researchers portrayed technologies as solutions to societal problems, for instance, when the PI states that developments of recycling technologies for metals are a potential solution to geopolitical conflicts over resources and inhumane mine work (Record 2 2, Pos. 72-74). This viewpoint on technoscientific problem-solving aligns with the technological deterministic rationale that “technological breakthrough can be claimed to have important social consequences” (Wyatt, 2008, p. 169). Wyatt described this as the “second part” (2008, p. 168) of technological determinism: to believe in the linear influence of technologies, such as plastic production, on societal issues, like pollution. This means-to-end and goal-oriented thinking in sustainability practices reflects aspects of the data analyzed on *caring-for* the future, where the participants describe their present practices as working towards something ahead.

Another statement that connects to technological determinism is when a participant talked about research through circular/pyramid scheme metaphors, which was analyzed in section *6.1.3.2. Context and Collectiveness*. This represents the belief in achievement through academic research that operates on a trajectory towards progress — a technological deterministic approach (Henwood & Marent, 2019). In general, the self-understanding of the researchers is based on long-term goals with step-by-step thinking in their Green/sustainable Chemistry practice.

However, these circular/pyramid scheme metaphors also point towards a view of this development as not necessarily a linear trajectory of science and technology but one with turns and stops. Research historically has been complex and ambiguous in its interconnectedness and process of knowledge production (Collins & Pinch, 1998). However, it still is connected to the rationale of technological determinism, that technoscientific research, such as chemistry, improves continually on a certain trajectory that might not be linear (Matthews, 2021).

In the next section, I will discuss where participants’ statements on their practices in Green/sustainable chemical practices did not comply with the viewpoint of technological determinism.

7.1.1.2. Technological Determinism?

This section will discuss whether technological determinism exists in the participants' statements and their views on sustainability. This presence is contradicted by the participants reflecting on political-societal influences on technological developments. This was analyzed in section *6.2.2. Political Aspects* and their sub-sections. Furthermore, the researchers acknowledged how the interaction between their practices and other societal actors is also relevant to their research and sustainability issues, e.g. Green Chemistry Austria, investment, science communication, education. The research's care for community, togetherness, and personal value is a relevant and central social factor in chemical work. This is also related to how participants see their practices as part of a more significant process, not the solution per se, as analyzed in section *6.1.3.2. Context and Collectiveness*. This again demonstrates the reflectiveness of their impact, as argued in *6.1.2. the dissenting-within* section. The acknowledgment of social relationships–between political and personal dimensions–contradicts the "first part" of technological determinism as described by Wyatt (2008, p. 186). These kinds of ambiguous statements in the data speak to more fine-grained views of the researchers on the intertwinement of science and technology with historical, *ecological* and societal trajectories. These differing viewpoints in relation to how the interviewees understand sustainability in their practices may be described as lying on a continuum between technological and sociological determinism (Matthews, 2021). Ultimately, the researchers diverge from each other and in their own statements regarding technological determinism. The conflicting viewpoints might coexist in their daily chemical practice to care for their *ecological* and societal impact in today's socio-technical entanglements. A belief in technological determinism to a degree might be necessary to work towards a goal within academic research to think for the "environment" (e.g., Record 2, Pos. Pos. 76 or Pos. 67-68) and the "future" (e.g., Record 3_2, Pos. 5 or translated, Record 4, pos. 38). As Wyatt writes and as previously quoted in the theory section:

> "Some actors, some of the time, present projects as simple and straightforward. It is necessary for them to do so to make things happen and to justify their actions." (Wyatt, 2008, p. 174)

It is also parallel to many other sustainable fields and our everyday life of trying to make things more sustainable, hoping it might help with the available knowledge of what might cause damage. The interviewed researchers are self-reflective and critical about academic research and industrial applications to be aware of turns and damaging societal and *ecological* effects. They frequently refer to the impact of academic and social relations, being in the early stages of research and referring to the Green Chemistry community or the chemical scientific

community in general. They reflect the pitfalls of techno-scientific developments and the mutual relation between societal and technological actors regarding sustainable impact and their practice in general. The interviewees' statements highlighted the historical, present, and future pitfalls of chemistry, which have led or continue to lead to planetary damage or include discriminatory and/or pressuring hierarchical structures. This does not exclude the viewpoint of the “second part” of technological determinism, that technoscientific development inevitably influences society. However, this critical self-reflection does not idealize the influence of technological developments. It is not manifesting the “equation of technological change with progress” (Wyatt, 2008, p. 172). Technological determinism, whether present or not, is not what causes inevitable sustainable change for the participants: taking active part and reflecting in laboratory practice is. Sustainability can only be explained in the participants statements through taking various interrelatedness from community over institutional to chemical structures into account.

7.1.2. Transcendence and Immanence

In this section, based on the data, I will link my thoughts on the binaries of transcendence/immanence with my research question of how sustainability is understood in the everyday laboratory and the discursive practices of the researchers.

The binary conceptualization of transcendence/immanence and scale/no scale and the blurred lines in-between observed by Papadopoulos (2022) in his research applies very well to the often-mentioned aspects of basic and applied science of the interviewees' chemical practices. The binary of basic and applied research and the in-between connections is related and relevant to the participant's understanding of working in Green/sustainable Chemistry. First, the participants connect having these aspects in their chemical practice to the personal level, e.g., motivation and/or enjoyment for basic and/or applied scientific work. They also understand the basic/applied binary as important on an economic and political level, e.g., if companies take “the risk” depending on the application possibilities ((Record 2, Pos. 104) and how/if practices potentially works out outside the laboratory, etc. Connected to these previous levels, basic and applied scientific aspects are relevant in the laboratory because they motivate the researchers working in the lab, are economically relevant, decide if they can make industrial applications possible, and so forth.

Regarding the interviewees' understanding of these two poles of science in relation to societal and *ecological* influence, the binary becomes more blurred. Possible future mundane or medical applications (mobility, house building, etc.) of their scientific work seemingly motivate researchers to try different practices regarding basic chemistry research connected to their understanding of sustainability. The research indicates that Green/sustainable Chemistry is a space in which the interviewees can connect applied and basic science aspects.

Papadopoulos's observation of transcendence and immanence in Green Chemical Practice (Papadopoulos, 2022, p. 120) sidelines this viewpoint of the participants. The constant, transcendent questioning of how research developments can be applied beyond laboratory boundaries and have an impact on an industrial level is present in this field and in my ethnographic observations. Simultaneously, immanent aspects, like experimenting with different temperature conditions in the laboratory setting, are also part of the considerations linked to basic chemistry approaches.

Understanding this duality of aspects helps explain how participants in this study approach and see sustainability in their practice: trying to be sustainable is part of their considerations of basic and immanent, as well as applied and transcendent aspects. The next section will illustrate the intersection of these poles in the laboratory influencing and being influenced by sustainability considerations.

7.1.2.1. Practices of Transcendence and Immanence

This section will focus on how transcendence and immanence in laboratory practices affect and are affected by the participants' understanding of sustainability in practice.

In the interview with the PI, the transfer issue from the "laboratory phase" to widening it to areas of industry and mundane life is something that is often an issue with chemical practices being applied (Record 22, Pos. 16). It involves immanent and transcendent considerations: How can the synthesis be scaled up on an industrial basis? What can be issued outside of laboratory conditions? How can we ensure our experiments minimize risk and maximize success for industrial-scale production and distribution? The PI mentions the "long way" ahead toward the "industrial" application of a more sustainable chemical practice because there are practical obstacles to going from the laboratory to the industrial phase. Here again, envisioning sustainability through laboratory practice is linked with technological deterministic viewpoints, which are long-term goals and linear thinking as discussed in the previous section. Besides these problem-solving understandings of sustainability in practice, the intrinsic or immanent science aspects (Papadopoulos, 2022), e.g. chemical synthesis steps, are simultaneously seen as a playground to experiment with what is possible ("potential products"). Both characteristics–applied and basic aspects–aid to promote financial, infrastructural, or political investment and interests. This is crucia. for the vision of CO_2 valorization complying with *ecological/*sustainable and industrial/economic ideals.

Another aspect that positively underlines the relationship between practices that are "small scale" and "in the present" with practices that are in the "future" and "large scale" practices is exemplified in the following quote (translated, Record 4, Pos. 38-40):

> "Dream, of course it's a utopia at the moment, but that there could be a factory where you practically switch off the CO_2 and then use it directly" (Record 4, Pos. 38-40).

This quote links "utopia" and forecast to their current laboratory work. Laboratory practices are enacted through non-human actors on a material basis: "Ionic liquids" or "organometallic frameworks" are the material-methodical bridge between different chemical approaches that are applied to achieve the vision of sustainable practice (translated, Record 4, Pos. 38-40).

7.1.2.2. Interrelatedness as Part of Sustainability In The Practice and Self-Understanding

The interviewed researchers' description of their practice emphasizes the importance of interrelatedness instead of separation between and isolation of various dual aspects for them and their research (goals). Those can be academia-industry, small-large scale, utopia-current practice, transcendence-immanence, toxicity-safety, field-laboratory, and fundamental-applied approach. The interviewees were motivated to examine these complex interrelations in the field. Moreover, these dual poles can be seen as on a spectrum, where the research falls somewhere in between.

From the participants' descriptions of their sustainable practices, I understand that there is a coexistence of different scientific approaches in their research, which are interconnected. Considering their understanding of sustainability in research, applied and basic chemical aspects are relevant. For instance, the resourceful circular "utopia" mentioned earlier can be worked toward, where CO2 is produced and valorized. Transcending laboratory realization has to be based on immanent considerations in practices.

This section covered how two conflicting and overlapping areas, basic and applied science, help explain the role of researchers' understanding of sustainability in their research.

7.1.3. Political Reflection on Their Influence and Sustainability

This last section aims to answer the sub-research question of how sustainability is understood in the everyday laboratory and the discursive practices of the researchers by considering political and ethical aspects in their reflections.

I will start by discussing the relationship between power and approaches to sustainability. As one participant noted, everyone can contribute by focusing on "their own part" to foster a more sustainable future (Record 3_2, Pos. 5). Yet, this is still a kind of power over knowledge production, even if it is partial. Acknowledging "their own part" means reflecting on sustainability and its effects and not leaving this practice to philosophers (Record 3_2, Pos. 5). Therefore, the researchers are aware of their responsibility but diminish its importance and magnitude by pointing out that they can't define sustainability. The simultaneity shows that it is possible to do a practice based on something that is not concretely defined/definable ("sustainability") and still hold some responsibility for it. In line with acknowledging one's responsibilities, one must be "honest" (translated, Record 1, Pos. 58) about the implications of laboratory chemical practices, as argued by a participant. The striving for the realization of sustainable imperatives in chemistry presents challenges due to using resources and the inherent non-sustainability of certain practices. The practical and ethical approach the PhD student is taking is to accept the unknown and uncertainties while also being "honest" (translated, Record 1, Pos. 58) about the effects it might have that are not sustainable long-term. The approach for honesty about uncertainties and non-knowledge in chemical research differentiates from other research and policy approaches, where strategic ignorance and shallowness over unsustainable effects are present. In addition, the participant mentions how short-term and alibi sustainable causes are presented to the front, hiding the ignorance over unsustainable long-term effects, backed by literature (see Alonso-Calero et al., 2022). In this case, the participant *dissents-within* the sustainable Chemistry field and economy with Greenwashing. The researcher cuts relations with the habit of advertising superficial apparent success in sustainable chemical development, strengthening other caring relations with genuinely sustainable goals. It connects to the critical reflection on Greenwashing within the chemical community and industry, which is talked about in the analysis in sections 6.1.2.4. "*Dissenting-within* Green/sustainable Chemistry through maturing collectively" and 6.2.1.3. "Nachhaltig/Sustainable". In the latter, criticism was voiced by one participant towards labeling chemical practice with "sustainability" that is not entirely accurate/"honest" (translated, Record 1, Pos. 60). However, the researcher acknowledges that long-term sustainability can never be fully guaranteed. This section pointed out, based on the analysis, how the participants understand sustainability in the wider political and ethical context and their situatedness in this discussion ("their own part").

7.1.4. Concluding on the First Sub-Question

In the past sections, I have discussed several aspects connecting the chemical practices of the participants and their considerations on sustainability. I perceived technological deterministic viewpoints, like achieving goals through chemical development, only to a certain extent as part of how they approach sustainability in their work. Simultaneously, the interview revealed contrasting viewpoints in the interviews, particularly the societal relevance described to sustainability on their techno-scientific practices. In the next section, I sidelined immanence and transcendence (Papadopoulos, 2022) with basic and applied science aspects to explain how the understanding of sustainability plays a role in combining those poles. Bringing diverse approaches together, like considering fundamental aspects of substrate choosing or industrial upscaling, is motivated by the envisioning of sustainability through chemical practice while it also shapes this vision. Lastly, I argued how the reflection on sustainability by the participants can be considered politically. In their described understandings they sometimes detach themselves from the political sphere, while also seeing the power and ethical aspects of applying a certain understanding of sustainability.

In general, the understanding of sustainability is ambiguous, entails contradicting and co-existing aspects, and is individual per participant and collective in the Green/chemistry community.

7.2. *How Do Actors Care for Chemical Toxic Pollution Through Their Practices?*

My thesis answers this question by discussing the participants' views on and practices of pollution, toxic substances, and resources. I focus on the pollution and toxicity aspects of caring relations in modern chemistry because of the field's *obligation* towards *ecology/ies* (Puig de la Bellacasa, 2021). Toxic chemicals and waste are also relevant to the participants, as these topics come up frequently in interviews and ethnographic work.

I will start by illustrating the participants' view on caring for pollution through two examples from the analysis section: an experiment to mirror photosynthesis and the usage of carbon monoxide in everyday lab practice. Both cases allow for an interpretation through the lenses of technological determinism and toxic politics. Then, I will connect this to a perspective on complicity and compromises concerning the arguments made before. Before concluding on this sub-question, I will discuss caring for pollution as a question of power.

7.2.1. Mirroring Photosynthesis for Pollution Reduction

In this section, I will discuss an observed experiment performed by a participant to illustrate how they care through their practices for pollution and toxicity.

In this experiment, the researcher explained an experimental design of chemical steps, which they follow to get closer to mirroring the "natural" photosynthesis in plants. With this, they want to transform carbon dioxide into new chemical components. As they say, the "end goal" is to create an imitating synthetic process; this is a relevant part of the project's CO_2 valorization prospects (fieldnotes__2, Pos.11). The idea of "mirroring" a "natural" phenomenon speaks about how laboratory chemical practices are seen to have to replace or supplement chemical practices happening in living organisms (fieldnotes__2, Pos.25). Plants are living beings capable of photosynthesis, which reduces the heightened CO_2 emergence in the air. This "end goal" speaks of a perceived need for anthropogenic technologies based on processes inherent to non-human organisms, which are perceived as insufficient to counteract the effects of human-made technologies. This idea that scientific chemical progress helps change issues of pollution and toxicity, such as greenhouse gas emissions, can again be interpreted as technological deterministic arguments. Here, the assumption of the technological fix as *caring-for* the environment is manifested (Puig de la Bellacasa, 2011). However, this experimental design also foregrounds a different viewpoint: sustainable practices can help an *ecological* system that have long functioned through proactive ways to reduce pollution and toxicity. As Papadopoulos writes about *anthropochemicals*:

> "*Anthropochemicals* implicate us and we need to remake them differently in order to escape them. We escape with them rather than from them. In a sense the antidote to chemicals are chemicals" (Papadopoulos, 2022, p. 119)

As this quote reveals, alternative *anthropochemical* practices can be acts of healing in a world *ecological*ly damaged by *anthropochemical* practices and their toxic polluting effects. Care for toxic pollution can come through rethinking practices that caused it.

7.2.2. *Toxic Politics* Reflected in the Laboratory

In this section, I will focus on how polluting practices in the laboratory can be inherent to practices caring for reducing pollution.

The previously mentioned synthesis that aims to mirror photosynthesis illustrates this paradoxical relation since methane is also produced. The researcher explains the acceptance of the minimal dosage of methane, underlining that pollution cannot be avoided in total and that it is, as cited before, a "less toxic pollutant." But how high will the amount be when such a synthetic process is industrially scaled up? Another issue of chemical pollution connected to the laboratory project of CO_2 valorization touched upon in the interviews is the usage of carbon monoxide (CO), which is classified as "poisonous" (Record 3_11, Pos. 19). As highlighted in the analysis, here the embodiment of living beings is involved in displaying the toxicity of the substrate ("you shouldn't breathe it in", Record 3_1, Pos. 19). Despite its hazardous nature, CO is used because it is more "reactive" than CO_2 (Record 3_11, Pos. 19). Using CO_2 by converting it into CO is a translation of the CO_2 pollution issue into a solution approach. The necessary practices and intermediate substances are connected to toxicity and potential planetary harm; hence, they are attached to risks. This potential is then minimized, e.g., through a "closed environment" in the laboratory (Record 3_11, Pos. 19). Here, the participants apply in their practice and statements a means-to-end rationale. However, they reflect on the risks and non-sustainable aspects of the processes of valorizing CO_2. The technological deterministic argument that scientific progress is the ideal, even with the risks attached to it, can be interpreted as present in this viewpoint. It also speaks about a form of *toxic politics*. The risks are fewer than in "the current state of art" as one participant formulates it (Record 3_2, Pos.30). It applies to *toxic politics* and *slow activism* because the participants do not expect purity but try in the context they are to care ethically about their practices and polluting effects. At least, this aligns with my observations during the two lab days. They were in multiple

practices related to waste and pollution, aware of the potentially toxic impact, and open to discussing this in the interviews.

Considering the potential necessity of accepting of producing pollution and waste brings me to another aspect, with which I conclude this section: complicity and compromises (Murphy, 2017; Shotwell, 2016)**.** Actors in chemistry (consuming products or synthesizing them) make compromises to make this world less toxic and polluted. They are further complicit with structures producing toxic chemicals for other goals and rationales, like the need for medicine and safety. One example that supports my argument is this quote, which highlights the participant's awareness of the compromises involved in being part of a network of diverse interests, caring relationships, and habitual practices in chemistry:

> "As good as possible, yes, I see always the waste mountains as well so... so that is... I can't avoid it totally so to say." (translated, Record 44, pos. 104)

The knowledge of limitedness in actions against and awareness about non-knowledge of how their practices can have polluting and toxic effects are displayed in the data. Moreover, there is the acknowledgment of further responsibility of modern chemical practice in the past and the present. Their actions are complicit with toxic, wasteful chemical practices ("everything is toxic in theory", fieldnotes_1, Pos. 34). However, this compromise towards pollution is perceived as needed for the small steps they are taking toward caring for a less polluted planet, for the *ecological obligation* of doing something meaningful "for the world" (translated, Record 11, Pos. 18) and to resist institutionalized damaging structures.

By investigating my question about how actors care for toxic chemical pollution through their practices, I find that they are compromising, complicit, and resisting chemical practices.

7.2.3. Power Related Reflections

In this part, I will discuss how it is also a question of the power and influence of how to care for pollution in Green/sustainable Chemistry.

The question of deciding “what […] to create, and at what cost” (Papadopoulos, 2021, p. 59) is integral in everyday laboratory practice: The participants make day-to-day decisions (experimental conditions) as well as long-term decisions (deciding on a project) and are granted with these choices through institutional, social and personal resources. This has *ecological* consequences, as their chemical practices are connected to pollution and toxicity, as they acknowledge. Simultaneously, it is a restricted power of impact with so-to-say blindsight. As the participants repeatedly emphasize, their approach is often a matter of "trial and error" (Record 3_22, Pos. 5), and they are uncertain of the outcomes and costs involved. The researchers must gain the ability to decide day-by-day through tinkering, experimenting, and finding out the effects. They can draw on knowledge about chemical practices other actors produce, e.g. by reading literature or exchanging at conferences. In sum, researchers depend on ecologies of academic knowledge, their lab, and the properties of chemical processes.

Ultimately, regarding the political question of who makes decisions over harm/benefit-implying practices regarding chemical pollution, it means acknowledging the power of knowledge production in their actions and their *obligation* towards *ecological* reparation. This does not imply that they are not limited in their impact or are culpable of unintended damaging consequences, but their practice comes with a responsibility. In contrast, genuine caring reflections are important towards themselves and their relation to their practices and the *ecology/ies* they may influence.

7.2.4. Concluding Thoughts on How Actors Care for Chemical Toxic Pollution Through Their Practices

How participants care for pollution through chemical practices is shaped by compromises and complicity within the academic and industrial chemical structures the lab and research is situated in. It is further shaped by resisting and questioning thoughts about polluting practices. In the end, it is a technoscientific and political question as to where the limits lie, what resources are available and which interests are conflicting.

7.3. *For Whom and What Is (Not) Cared For?*

In this section I will focus on how my thesis answers for whom and what is (not) cared based on analyzing how the participants relate to different entities in caring ways through their knowledge practices. These include more abstract entities, e.g. the future, everyday objects of the laboratory, their social relations, values of sustainability, and so forth.

7.3.1. Caring For the *Other*

As highlighted earlier in the analysis chapter, knowledge practices of caring for can involve the construction of *otherness*. This creating *otherness* became especially true for *thinking-for* practices. However, this perspective raised more questions than answers and revealed that what the *other* meant to them was not thoroughly discussed in the interviews. In the following, I discuss constructing *otherness* through questions around an entity the participants cared for and became *other*: the environment.

Considering caring for the "environment", the following questions arise: Do the participants perceive themselves and their practices as an integrated part of an *ecological* system? Or do they imagine themselves as distinct actors having "an impact on" (Record 22, Pos. 76) and being affected by the *other* - "the environment," "world," or "humanity" (translated, Record 11, Pos. 18)? I cannot definitively answer this because "environment" or "humanity" as concepts were not discussed in their meaning in the conversations. For instance, everyday use of the term "environment" can also represent a more holistic approach to ecologies. One hint that was given was when one actor added themselves to the list of entities they want to affect, thereby situating themselves in the *ecology* they are acting in:

> "I want to generate some meaningful input for the world, for humanity, for myself" (translated, Record 11, Pos. 18).

Regarding this more situated creation of *otherness* in a statement, where one cares and thinks for another entity ("world"/"humanity"), but also includes themselves in giving something ("input") the following quote is relevant:

> "Creating significant otherness is a process rooted 'in vulnerable, on-the-ground work'" (Puig de la Bellacasa, 2012, p. 207)

I conclude that this quote and the reflection on thinking for "environment" mean the lab members must acknowledge their limitations, their involvement, and the potential critical sides of caring and thinking for *others*.

7.3.2. *What Is Not To Be Cared For?*

This section will discuss the knowledge practices summarized in the last chapter that discontinued or resisted relations to establish or strengthen other caring practices. Not (anymore) *caring-for* entities were connected to the idealization of sustainability, the "Green" label, and issues regarding industrial, economic, and institutional structures. What did the participants *dissent* with and *within* which circumstances?

In this study, I investigated practices and relations of non-human (e.g., used materials) and human actors (e.g., study participants) within the institutionalized modern chemical practice, which has been polluting the world with historical continuity (Liboiron et al., 2018). I observed how these actors tried to *dissent-within* this network of toxic/polluting/damaging relations between practices and actors, for example, by discontinuing the use of certain machines to care for chemistry's *ecological obligation* (Puig de la Bellacasa, 2021, p. 220). The statements that rethink unsustainable parts of their lab and consider alternative ways of doing have also partly a paradigm of improvement integrated into them: recognizing a practice that doesn't involve *ecological* care, questioning it, and then changing the path. It is strived for and considered in their work to search for more sustainable ways with acknowledgment of their limitations, damaging habitual behavior, and non-knowledge, as I would argue. Furthermore, I interpret the change of practices, through caring-for reflections, as humble approaches to not idealize their impact and actions. The participants viewed the context of what was done before and now within the conditions of institutionalized academic lab practice, which also causes chemical pollution.

Another aspect of cutting relationships of care to foster others was seen concerning academic structures. The PI tries to *dissent-within* the academic culture from pressuring (Vigil Avilés et al., 2024) and mental health-impacting (Levecque et al., 2017) structures. This is a way to foster a more caring atmosphere for the PhD students and in the laboratory, which I sensed to be real from my conversations and visits. However, a caring atmosphere is not perfectly achieved, and stress and frustration are not glossed over in the interviews with the PhD participants. As the article by Kerr and Garforth (2016) shows, caring relations created by the PI influence work and research. To pick up the *thinking-for* practice aspect following the earlier section, *care* in laboratories can be ambiguous, as highlighted by the case study by Kerr & Garforth (2016). In my research, in contrast, I received a genuine caring feeling from the interviewees. While collecting data, I experienced the participants being in an enjoyable working environment.

Lastly, I will discuss this statement of the PI concerning *dissenting* practices *within* research with financial topics:

> "Luxury, that I can research that without the requirement to make it financial viable in the beginning" (Record 2, Pos. 76)

The characteristic they see in "the field of sustainable chemistry" and, in extension, in academic research as a contrast to working in a "company" is this independence from financial "requirements" (Record 2, Pos. 76). However, discussion of cases in STS literature show that in academia there are still capitalist structures of accumulating value at play and that "financial viability" (Hessels et al., 2019, p. 138) still plays a role (Etzkowitz, 2013; Fochler, 2016; Hessels et al., 2019; Pinel, 2021). The interviewees also acknowledged the importance of investment in some citations (see section 6.2.2.3. on Financial Actors). However, I interpret the statement of the PI's work that in their specific case, possibly because of the ERC grant, in contrast, analysis 62.3. on financial actors). The aspect of a research outcome is not so strongly tied to an economic "requirement" as it may be in other fields and groups.

Ultimately, this aspect of caring has highlighted how relations, practices, and habits are changeable or can be imagined to be changed. Abandoning something and leaving something behind can mean room for something new. Not idealizing a label can lead to an open, realistic mind toward what can be done and what is done. Questioning structures in academic chemistry can offer new feelings of togetherness, support, and freedom. As I experienced in my study research, not caring for something can mean the possibility of caring for something that was in the shadows before.

7.3.3. *Caring For the Community and the Self*

In this last section, I will discuss a specific assemblage that is cared for central to practices for the participants: community. The community involves colleagues in their labs, other labs in the same building, worldwide, which are met at (online) conferences. There are different sides to exchange and relationship building, such as the before-mentioned conferences or shared rooms/buildings/institutions. However, publishing is also a way of discussing knowledge, associations, project collaborations, and initiatives. The specific community of Green/sustainable Chemistry and other specific chemistry disciplines (like electrochemistry) are important to the participants in the lab.

The role of the community and its sides is significant to their research about sustainability—they are part of their knowledge production processes, their relationship building, the estimation of the field in its sub-areas, and giving orientation and expectations for how to be more sustainable. Here, the researchers' awareness of the entanglement between social relations and chemical practices is demonstrated.

Other aspects entangled with caring for the community are personal relationships, as friendships and togetherness are highlighted in the interviews. One participant, for instance, explained the “privilege” to have close–emotionally as well as spatially speaking–friendships with others in the chemical community who understand their struggles (Record 3_22, pos. 46). Personal relationships also include those inner caring relations, that are analyzed in section 5.1.3.1 and “Personal relatedness” as well. Those caring practices for personal relatedness and community in laboratory work involve feelings, embodiment, and thoughts.

7.3.4. Conclusion on *For Whom And What Is (Not) Cared For?*

In this section, in answering my third sub-question for whom and what is cared for in the laboratory, I considered *other* entities and the entities the participants situate within. Further, I illuminated how resisting or discontinuing caring is connected to starting and maintaining caring. What is not cared for (anymore) gives space to new caring practices.

7.4. How Do Actors Practice Care in The Context of Sustainable Chemical Practices in The Laboratory?

I will approach my main research question on how the actors care about sustainable chemical practices in the laboratory through *slow activism* (Liboiron et al., 2018). The previous discussion of answering my three sub-questions has shown that caring in this research is influenced by sustainability, pollution, toxicity, and chemical research practices. These practices involve understanding, handling, experimenting and more. They can be individual and collective, including humans and non-humans (like devices, environment, and publications). They involve emotional bonds to friends, personal values, the wish to contribute, reflectiveness over one's actions and limitedness, and practices based on material and knowledge relations. These dimensions and shades of care practices and relations in the studied context, a Green/sustainable laboratory, reminded me of the concept of *slow activism* (Liboiron et al., 2018) introduced in the SOA. It did because several features described by Liboiron et al. (2018) matched the data I gathered on laboratory practices that aimed to care about pollution and toxicity. The following section will elaborate on this interpretation.

First, the caring practices analyzed could be seen as "toxic politics within but beyond governance-via-policy, in-the-streets-activism and science-as-usual" (Liboiron et al., 2018, p. 337). However, even if laboratory researchers do things differently, their practices and conditions align with science. Hence, I want to specify those small moments I witnessed of tinkering or weighing options to deal with toxicity and waste that question long-done chemical and scientific practices in academia. I also reflected on their situatedness and caring relationships as possible moments of *slow activism* (Liboiron et al., 2018). These moments are presumably part of everyday scientific life in this lab and Green/sustainable Chemistry. This section does not focus on the bigger picture of science-as-usual and the collective movement of a scientific community; it is about small actions that nevertheless *dissent-within* science-as-usual. These practices of *slow activism* are often "intimate" (Liboiron et al., 2018, p. 342) and can involve friendship relations or moments of self-reflection (see "Sort out a lot in myself" translated, pos. 48, Day 4; Latimer & López Gómez, 2019). Further, the participants speak of daily practices that involve their own bodies and emotional state ("frustrating", Record 3_2, Pos. 46). In the following, I include what one participant explained when speaking about the relations between the personal state of being and their day-to-day work: How the lab days are going, is "tagesform-abhängig", which is a German adjective describing that something is dependent on how one feels and in which state one is on that day. They add that sometimes they are in a flow of work, sometimes not, and do different things depending on the day (fieldnotes_2, Pos. 44).

These intimate actions of care are “slow and small” and constitute imperfect changes and a step-by-step pace with mistakes and setbacks involved, as described above. The participants' actions are also part of understanding the ethical implications of what they are doing and could be doing, as I heard from how they speak about sustainability. It is about how they could contribute to finding more sustainable practices in chemistry that are less damaging to the planet. Being reflective of their values in conversations with me and acting upon them make another argument for seeing the participants’ actions partly as moments of *slow activism*:

> “toxic politics that do not necessarily result in scaled-up material change, but constitute material ethics at the immediate scale” (Liboiron et al., 2018, p. 341)

The ethical, imperfect, and embodied actions hint for me, therefore, towards “toxic politics” involving *slow activism*–the researchers are reflective about their limitedness. Nevertheless, there were moments when the participants delineated themselves from politics which I do not want to overlook, especially given that *slow activism* is defined as *toxic politics* (Liboiron et al., 2018). One participant highlighted, for instance, if they would talk about the financial aspects of sustainability and their project, they would have to go “into politics” (Record 3_22, Pos. 8). In another interview, the PI spoke about “the large groups, the 3 pillars academic, industry, and politics”. Through this, they situated their practices and laboratory actors in the academic “pillar,” which must establish communication links to the *other* “large groups” (Record 2, Pos. 106). In these cases, I think different concepts of politics are meant (see Brown, 2015). The quotes speak more of the institutional area of political parties and groups, governmental actors, and political science. However, politics, as understood in my application, leans more on a power-critical understanding. Knowledge practices of experimenting, exchanging through conferences and publishing, and establishing methodologies are non-innocent; they affect the world and its political and social situatedness (Michael, 2017b). These knowledge practices are, in their entanglements with the contexts and actors shaping them and shaped by them, part of political ecologies and politics (Puig de la Bellacasa, 2011; Galis & Hansson, 2012).

In this discussion, I illuminated how I approached the main research question through my ethnographic research on a Green/sustainable Chemistry laboratory based mainly on the conceptualizations of *matters of care* (Puig de la Bellacasa, 2011) and the strand of Laboratory Studies (Knorr Cetina, 1995).

8. Conclusion

Lastly, I will end my thesis with a conclusion on my arguments, a reflection on my situatedness and research process, how it contributes to STS literature and opens pathways for more research. In this research, I explored the entanglements of care and sustainability within a Green/sustainable Chemistry laboratory. I combined ethnographic methodologies leaning on the strand of Laboratory Studies (Knorr Cetina, 1995) with the theoretical framework of *matters of care* (Puig de la Bellacasa, 2011) based upon the Actor-Network theory (Latour, 1987). Moreover, I included concepts of technological determinism (Wyatt, 2008), transcendence, immanence and scale (Papadopoulos, 2022), *slow activism* (Liboiron et al., 2018, p. 341), and *ecology/ies* (Papadopoulos, 2021). and *obligation* (Puig de la Bellacasa, 2021; Papadopoulos, 2021).

Throughout my thesis, I illuminated ways researchers navigate the pressures of reducing chemical pollution to care for the *ecology* while being situated in scientific practice within the current socio-economic structures. I examined everyday laboratory practices, studying how Green/sustainable Chemists care for a polluted planet while remaining entangled in systems perpetuating *ecological* damage.

My research underscores how STS perspectives, e.g., *toxic politics* (Liboiron et al., 2018, p. 333) sensitize toward the role of chemical laboratories as sites of both harm and care. Laboratories are not neutral spaces but are deeply embedded in political, economic, and *ecological* contexts. The participants' efforts to valorize excess CO2 and adopt sustainable practices reflect resistance to current toxic polluting practices. Nevertheless, these endeavors also expose tensions between care for sustainability and the material realities of chemical production, such as toxicity and waste management. My findings suggest that care is not an abstract ideal but is situated and defined by real practices and relations. It involves negotiating competing interests and navigating institutional, economic, and techno-scientific constraints.

From a broader perspective, my study contributes to ongoing discussions about the interplay between science, technology, and *ecological* justice. I emphasize the importance of integrating decolonial and anti-colonialist approaches into sustainability discourses, like questioning the term *Anthropocene* in current discourse (Yusoff, 2018). Historical and systemic inequities, particularly those rooted in colonial and capitalist frameworks, continue to shape global chemical practices and their *ecological* and social impacts (Murphy, 2008). By foregrounding these interdependences, I advocate with this research for a more critical understanding of *ecological obligation*s within fields of sustainable practice.

Reflecting on my situatedness as a researcher, my academic background, and my positionality as a white and privileged individual, I recognize that this thesis is not written from a neutral and objective perspective. My experiences and the tensions between compliance

and resistance to industrial systems influence my research. Acknowledging my position within these complex networks of privilege and harm is part of the anti-colonialist and feminist approaches I included through my conceptual lenses in my thesis. For instance, *matters of care* (Puig de la Bellacasa, 2011) and *obligation* (Puig de la Bellacasa, 2021; Papadopoulos, 2021) highlight the importance of one's positionality in power relations.

The experience of the master thesis process also reinforced my commitment to being self-critical of my situatedness in *ecologically* unjust systems. It has further shaped my professional trajectory: I gained a deeper awareness of chemical pollution, which influenced my decision to work on a project within an NGO, where legal actions are taken against toxic chemical pesticides. Acknowledging these dual influences—the way my situatedness shaped this research and how the research reshaped my commitments—highlights the intertwinement of a researcher between researching and lived experiences.

Based on my findings in this thesis, further research could investigate within a long-term ethnographic study how *slow activism* approaches are present in laboratory practices (Liboiron et al., 2018): Can prioritizing caring and localized efforts play a valuable role, and in which ways regarding, e.g. *ecological obligation*? It could explore the intersection of care and chemical practices more deeply. How do different forms of care—social, environmental, and institutional—shape and constrain Green/sustainable Chemistry? Moreover, what mechanisms can be developed to ensure that sustainability efforts do not reinforce existing power hierarchies? How can laboratories better integrate voices from affected communities whose experiences and expertise are often overlooked in scientific and policy-making processes? Finally, the research approach to examining Green/sustainable Chemistry laboratories across diverse contexts can reveal the cultural and institutional factors that shape practices of *care* and *ecological obligation*.

In sum, this research illuminates Green/sustainable chemical practices in laboratories and invites a broader reflection on the role of diverse matters of pollution and colonialism entangled with science and technology in shaping our *ecology/ies*. My thesis advocates for practices grounded in the commitment to social and *ecological* equity and a realistic, self-critical, and pragmatic understanding of caring for the *ecological obligation*.

9. Literature

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10. Appendix

10.1. Abstract – English

Soil, water, air, and bodies have become increasingly polluted by industrial-synthesized chemicals–partly hazardous, persistent, or climate-affecting. In this irreversible reality, I investigate the case of a Green Chemistry laboratory trying to use the excess pollutant carbon dioxide to synthesize more complex molecules, e.g., for use as medicines. The researchers' objectives are to find resourceful ways to reduce air pollution, which causes greenhouse effects in the current climate crisis, and to reduce toxic and/or petroleum-based chemicals. In this research, I conducted semi-structured interviews with the researchers of the lab and followed them in their day-to-day laboratory work. I based my ethnographical approach on the STS strand of Laboratory Studies as well as on the theory of *matters of care* by María Puig de la Bellacasa to be sensible of the researchers' practices regarding *ecological obligation*s. In this thesis, I will reflect on the researchers' viewpoints on sustainability, how to care for chemical pollution and toxicity, and what the researchers care and do not care for. By analyzing these results, I can answer my main research question: How do researchers in Green Chemistry laboratories practice care for chemical pollution through their sustainability efforts? By looking at different forms of caring, I find self-reflectiveness about the limitations of (their) academic chemical practices and involved toxicity and pollution. I learn about small and "more" sustainable steps, visions and hopes, techno-optimistic viewpoints, and community aspects. My research underscores the critical relevance of STS perspectives in understanding the role of chemical laboratories as sites of both harm and care. It adds to the various STS studies of chemically polluted realities and the inflicted and resulting injustices with a research approach that focuses on caring practices in the academic chemical field.

10.2. Abstract – German

Boden, Wasser, Luft und Körper werden zunehmend durch industriell hergestellte Chemikalien verschmutzt, die zum Teil gefährlich, langlebig oder klimawirksam sind. In dieser unumkehrbaren Realität untersuche ich den Fall eines Labors für Grüne Chemie, das versucht, den überschüssigen Schadstoff Kohlenstoffdioxid zur Synthese komplexerer Moleküle, z. B. für die Verwendung als Arzneimittel, zu nutzen. Ziel der Forschenden ist es, ressourcenschonende Wege zu finden, um die Luftverschmutzung zu reduzieren, die in der aktuellen Klimakrise den Treibhauseffekt verursacht, und giftige und/oder erdölbasierte Chemikalien zu verringern. In dieser Studie habe ich semi-strukturierte Interviews mit den Forschenden geführt und sie in ihrem Laboralltag begleitet. Mein ethnografischer Ansatz stützt sich auf STS-Laborstudien sowie auf das Konzept der "*matters of care*" von María Puig de la Bellacasa, um die Verhaltensweisen und Praxis der Forschenden in Bezug auf ökologische Verpflichtungen zu verstehen. In dieser Arbeit werde ich die Standpunkte der Forschenden in Bezug auf Nachhaltigkeit, den Umgang mit chemischer Verschmutzung und Toxizität sowie die Frage, was den Forschenden wichtig ist und was nicht, untersuchen. Durch die Analyse dieser Ergebnisse bin ich in der Lage, meine Hauptforschungsfrage zu beantworten: Wie gehen Forscher in Laboratorien der Grünen Chemie mit der chemischen Verschmutzung im Rahmen ihrer Nachhaltigkeitsbemühungen um? Durch die Betrachtung verschiedener Formen der Fürsorge erkenne ich Selbstreflexion bei den Forschenden über die Grenzen (ihrer) akademischen chemischen Praktiken und die damit verbundene Toxizität und Verschmutzung. Ich erfahre von kleinen und „nachhaltigeren" Schritten, Visionen und Hoffnungen, technisch-optimistischen Sichtweisen und Gemeinschaftsaspekten. Meine Forschung unterstreicht die kritische Relevanz von STS-Perspektiven für das Verständnis der Rolle von Chemielaboratorien als Orte von beidem, des Schadens und der „care" (Fürsorge). Sie ergänzt die verschiedenen STS-Studien über chemisch verschmutzte Realitäten und die zugefügten und daraus resultierenden Ungerechtigkeiten durch einen Forschungsansatz, der sich auf „care" Praktiken im akademischen Chemiebereich konzentriert.