A Network Approach for Distinguishing Ethical Issues in Research and Development

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ABSTRACT: *In this paper we report on our experiences with using network analysis to discern and analyse ethical issues in research into, and the development of, a new wastewater treatment technology. Using network analysis, we preliminarily interpreted some of our observations in a Group Decision Room (GDR) session where we invited important stakeholders to think about the risks of this new technology. We show how a network approach is useful for understanding the observations, and suggests some relevant ethical issues. We argue that a network approach is also useful for ethical analysis of issues in other fields of research and development. The abandoning of the overarching rationality assumption, which is central to network approaches, does not have to lead to ethical relativism.*

1 INTRODUCTION

In this paper, we present a network approach to ethical issues in technological research and development (R&D). We are concerned with how to distinguish and deal with ethical issues in technological R&D. The types of ethical issues we focus on are those related to the eventual effects of the technology being developed. Such ethical issues are often hard to distinguish for two reasons. One reason is the distance between R&D and the eventual application, in time, place and involved parties, while the ethical issues we are interested in commonly become apparent during application. By this stage, however, it may have become too difficult to deal adequately with the problems. The other reason is that R&D is not undertaken by individuals working in isolation, but it is done by people working in networks. What is needed is an approach that a) uses

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the involved actors and potential stakeholders as an entry for discerning ethical issues and b) can do justice to the different perspectives and perceptions of the actors involved.

We argue that a network approach is helpful in distinguishing the relevant ethical issues in R&D, and illustrate this with a case study covering the research and development of a new wastewater technology, the Granular Sludge Sequencing Batch Reactor (GSBR). We investigated this technology as part of a parallel ethical research project financed by the Netherlands Organisation for Scientific Research (*NWO*). The idea of such parallel research is that ethical investigations are carried out parallel to, and in close cooperation with, a specific technological R&D project. Our R&D project is being carried out at the Department of Biotechnology (Kluyver Laboratory) at Delft University of Technology (TU Delft). In the next subsection, we describe the technology developed, in 1.2 we outline the aim of our parallel research and in 1.3 we give an overview of the rest of the paper.

1.1 Wastewater technology

An important drawback of traditional biological wastewater treatment plants is their large footprint, i.e. the space the plant requires. This is the case both for continuous processes, like activated sludge treatment plants, and for batch processes, for instance sequencing batch reactors (SBR). In the latter design, the reactors are operated cyclically. During the first phase, the bacteria grow and in doing so remove nutrients. In the shorter, second phase, the sludge consisting of colonies of bacteria sinks to the bottom of the reactor, and the clean water is let out. The reactor is then refilled with untreated wastewater.

In the aerobic GSBR now under development, the bacteria grow in high-density granules. This means, one, that the time needed for the sludge to sink to the bottom at the end of each cycle will be substantially reduced and that the shorter deposit time increases the throughput of the installation and reduces the footprint. Two, the developers hope that the granules will accommodate a sufficient variety of bacteria including aerobic and anaerobic zones large enough to treat the sewage in one step; this idea is called the “plant-in-a-granule.” The trick is to make the bacteria grow in granules rather than in low-density activated sludge flocs. Note that this form of granulation does not involve any kind of genetic manipulation. Instead, the environment in which the bacteria grow is set up to trigger granulation. The focus of the research approach is on process technology rather than microbiology. This approach appears to have made the Delft group the international research leader in this type of water treatment technology.

1.2 Ethical parallel research

The technological research, aimed at bringing the above described technology to maturity, incorporates at least two scaling-up steps: one step from a laboratory scale model (0.003 m^3) to a pilot plant (1.5m^3), and a second step from the pilot plant to full-size plant. The lab model uses synthetic wastewater and discharges its effluent into the sewers, the pilot plant is semi-open, viz. with buffered influent, and the full-size plant is fully open; it processes all sewage water and discharges it into surface water. While such a scaling-up approach is evidently a risk-reducing strategy, the question may still be asked whether the chosen scaling-up strategy reduces risks optimally or even sufficiently. After all, the choice of the process technological parameters used to manipulate the growth of granules rests on certain, yet unproven, assumptions about which granulation mechanisms are at work. The question, therefore, arises of how this incompleteness of knowledge is dealt with, in the choice of scaling-up steps. Incomplete knowledge can lead to the introduction of certain risks.

Our parallel research project was designed to investigate the ethical aspects of the scaling-up steps involved in bringing the technology to maturity, with a focus on risks and uncertainties. These risks may become manifest in the research done during the development of the technology, and in the eventual use of this technology. Dealing with such risks is a moral issue because when these risks materialize, moral values are at stake, such as human health and animal welfare. Questions about the acceptability of the risks, about how much effort should be put in at what costs, and what should be spent on reducing risks are therefore considered to be ethical questions.[1,2] We will also address the ethical question about the responsibility of addressing risks issues when sewage treatment projects are developed.

1.3 Overview

The main aim of this paper is to present the way in which we have applied a network approach to the discernment of ethical questions in the R&D regarding the GSBR reactor. The working hypothesis of our paper is that a network approach is helpful in discerning relevant moral questions, such as those about risks and responsibilities, and is instrumental for an adequate assessment of these questions. Section 2 is an empirical section. In it, we describe how we gathered data about the risk perceptions of researchers and potential users by holding a GDR session with the relevant stakeholders. Additionally we present some observations based on these data. Section 3 is a theoretical section, in which we sketch network analysis as the theoretical background of our approach. Section 4 will be dedicated to how we applied our network analysis to the GSBR case. We show how a network approach helps us to understand our empirical observations. In section 5, we present an additional discussion about the added value of a network approach for discerning moral issues in R&D and for making a moral analysis of such issues. Section 6 consists of conclusions.

2 THE GDR SESSION[a]

In this section, we describe the results of a GDR session with the main actors and stakeholders. A GDR is an electronic environment used to facilitate brainstorming and casting votes on issues. During the session, we did not aim at a consensus among the

a. We earlier reported on the results of the GDR session at *Granules 2004*.[3]

participants. We rather wanted to trace potentially interesting agreements and disagreements about the risk assessments of the participants regarding aerobic GSBRs, and about how to cope with these risks.

2.1 Description of the GDR session

We invited ten professionals, all involved in sewage treatment technology, to participate in our GDR session held on 13 September 2004. The group consisted of:

- three researchers, who were involved in the aerobic GSBR project
- two researchers who were not involved in the project
- four individuals from different water boards, i.e. the bodies responsible for sewage treatment in the Netherlands, and as such, potential users of the new technology
- one person from *STOWA*, the Foundation for Applied Water Research in the Netherlands

The session was divided into three parts which were dedicated to the following questions:

1. What, according to the participants, are the risks of introducing aerobic GSBRs?
2. How do the participants assess the magnitude of these risks in terms of probability and impact?
3. In what phase of the research, design or use of aerobic granular sludge reactors should the parties involved address these risks?

At the start of the session, we explicitly defined the concept of risk as follows: "The *risk* pertaining to a new development is the product of the probability and the impact of an incident or process due to that development with undesirable consequences for people or the environment."

Our question about the main risks resulted in a list of eighty-three issues. This list was then reduced to a shortlist of seventeen risks.[b] Subsequently, we asked the participants to score the shortlist risks on ordinal scales of probability and impact. This resulted in a distinction between large and small risks and several medium-size risks. We recorded the discussions on audiotape.

2.2 Outcomes

During the GDR session, some researchers wanted to distinguish between two sorts of risks, which they called "risks *to*" and "risks *of*" the introduction and use of GSBRs.[c] Table 1 shows how we distinguished between the two in the shortlist of risks. Under

b. Comparing the first list and the short list, we found that in the distillation process, the participants sorted out redundant information and distinguished implicitly between relevant and irrelevant information. The complete information list will be used when we prepare the interviews with the participants.

c. Although we acknowledge that the two are causally related, it is appropriate to distinguish the two conceptually.

the first heading, we gathered the external risks that many new technologies commonly run when introduced into the market. We distinguished between risk concerning *political or social* aspects and *economic risks*. The more internal, technological or engineering risks were listed under the risks *of* the technology.

Table 1: Risks

Risks *to* the introduction of GSBRs

A. Political or social factors

1. Failure of a new technology may adversely affect innovation in general.
2. Stricter effluent requirements complicate the choice for innovative technology.
3. Perhaps it will be difficult to get a license.

B. Economic risks

4. Eventually, the costs of the installation turn out to be too high.
5. The home market perspectives may be limited due to innovation fatigue.
6. The returns on investment are too low when launched in foreign markets.

Risks *of* the introduction of GSBRs

C. Sensitivity of the treatment process

7. The installation cannot cope with influent fluctuations (volume, composition, temperature).
8. 'Beheersbaarheid' of the granules formation (explanation see text).
9. The process is unstable due to lack of self-regulation.
10. Expensive back-up mechanisms are needed in case the process stalls due to lack of robustness.

D. Risks directly due to the scaling-up

11. Certain factors can only be examined full-scale, not on lab or on pilot scale.
12. The pilot's local circumstances fail to be representative.

E. Meeting the requirements or secondary emissions

13. The process fails to meet the primary effluent requirements.
14. There are too much secondary emissions, in effluent or otherwise.

F. Other risks

15. Higher reactor vessels may cause the formation of foam.
16. Difficulties with sludge processing.
17. The operators lack competence.

With respect to heading *E* in table 1, the primary effluent requirements are those laid down by law; secondary emissions are not yet regulated by law but may be in the future. An example of future regulations is the requirement to treat effluent to the level of MTR-quality which defines the maximum allowed level of risk regarding pollutants in surface water.[d] It fixes, for instance, the maximum level of pathogens in surface

d. MTR is a Dutch acronym for "Maximaal Toelaatbaar Risiconiveau" which means maximal allowed level of risk.

waters, something the law does not mention in the current situation, except for special circumstances like bathing water.

Let us consider the two extremes of our data: the, according to the participants, most and the least hazardous risks. The most hazardous risks regarding impact and probability were:

- *the installation cannot cope with influent fluctuations (volume, composition, temperature)*
- the *controllability of the granules formation*
- *the process fails to meet the primary effluent requirements*

The first two pertain to the table heading *Sensitivity of the treatment process*, whereas the latter relates to the category of *Meeting the requirements*. The least hazardous risks were considered to be

- *the home market perspectives may be limited due to innovation fatigue*
- *difficulties with sludge processing*

The first was an *Economic risk*, whereas the latter pertained to the *Other risks*.

After the scoring of the risks, we asked the participants to state in what phase of the development of the GSBR technology the risks should be addressed. We defined ten activities or phases:

- mathematical modeling
- the laboratory research
- scaling-up to pilot plant size
- pilot plant research
- scaling-up to full-scale size
- full-scale design
- the operation of full-scale plant
- new regulations with respect to full-scale plants
- new regulations on research
- contracts with suppliers

Generally, the participants judged that most risks needed to be addressed at the pilot-plant stage of the research. Apart from that, full-scale design and the operation of the full-scale plant were considered to be important phases for dealing with the risks. Regulations for research laboratories were thought to be irrelevant.

2.3 Observations

On the basis of the GDR session we made four observations. In subsection 4.3, we will interpret these observations in terms of a network approach.

1) There was a difference in correlation of the probabilities and impacts between the scores of the researchers and the users. According to four out of the five researchers the correlation between the probability of an accident and its impact, was low ($0 \leq r \leq 0.3$); in contrast, for four out of the five users the correlation between probability and the impact was high ($0.7 \leq r \leq 0.8$). This is remarkable since, at a first glance, the probability and the impact of accidents do not seem to be empirically related.

2) Whereas the researchers from the laboratory were optimistic about the new technology meeting the *primary* requirements, the users of the new process were sceptical about this point.
3) The participants of the GDR session used the term 'beheersbaarheid' ambiguously. The translation of this Dutch term is "manageability" or "controllability". The potential users of the new technology used the word to indicate the *manageability* of the process of the working plant, to keep the process running whatever the fluctuations in the influent. The researchers, however, used the term to mean the *controllability* of the process, in the sense of knowing the mechanisms and the relevant input variables that determine the output variables. According to the researchers the probability of problems with the "beheersbaarheid" of the granules was medium, whereas according to the users it was high. This difference is in line with the ambiguous use of terms.
4) Four out of the five *users* of the technology delegated the *risk of secondary emissions* to the research phase, for which they are not primarily responsible, and three out of five *researchers* allocated the risk to a phase for which they bear no responsibility. Nobody therefore assumed responsibility for dealing with this risk. To be sure, this was not a general tendency with respect to all the risks. For instance, all parties claimed responsibility for *difficulties with sludge processing*.

3 NETWORK ANALYSIS

The GSBR technology is developed in a network of actors, and research decisions are made in the research network. Therefore, we considered it fruitful to analyze our case study from the perspective of a network of collaborating actors with different stakes and goals. In this section, we explain network analysis and the way we applied it to our case. In subsection 3.1, we describe the theoretical and historical background of network analysis; and in subsection 3.2, we explain how we used network analysis, i.e. which elements from the various network theories we applied, and which we passed over.

3.1 Background

In the last decades, network analysis has gained popularity in a number of disciplines like policy science and science and technology studies (STS). Klijn describes the development of approaches in policy science in terms of transition from a rational actor approach through a bounded rationality approach into what he calls the process model, in which the notion of network is central.[4] Whereas in the rational actor model, policy-making is seen as the activity of one central actor or decision maker, in the process model it is done by a variety of actors. In the traditional model, policy-making is depicted as taking place in phases that are set by a priori goals, whereas in the process model it takes place in a network of actors with conflicting interests and problem definitions. Instead of the policy-making process being guided by aims formulated beforehand, this process is unpredictable and dynamic and actors behave strategically. Decisions are not made based on what the best choice is in the light of the decision maker's goals, but are chosen because they generate enough support among the actors and can be linked to the problem definitions of the various actors. Whereas in the traditional rational actor model, information is obtainable and values are given, in the network approach, information is dispersed and ambiguous, and values are conflicting and often unclear. All these differences imply that where in the traditional model power is centralized, in the network model it is divided among the various actors.

In STS, a similar development in approaches is visible. Bijker for example presented his model for the social construction of technology (SCOT) in the eighties as an alternative to existing linear models of technological development, i.e. scientific invention, technological innovation, market adoption, which often have strong technological deterministic overtones.[5,6] In Bijker's model, the fact that actors will interpret a technical artifact differently and therefore have different problem definitions plays an important role in explaining the dynamics of technological development. The network approach was further developed and radicalized in STS, especially by Callon and Latour.[7,8] In this approach, known as actor-network theory, people refuse to make a priori distinctions between humans and non-humans; both are conceived to be acting entities.

3.2 Our approach

The use of a network approach seems appropriate for our goal because we are dealing with a situation in which research decisions are made by a variety of actors with different stakes, interests, knowledge, recourses, power, problem definitions and agendas. It is our aim to describe the network and the research decisions taken, and to evaluate them. In the past, network approaches have been applied to similar cases both in policy science and in science and technology studies.[7,9,10,11,12,13,14] Our project differs, however, from these past applications in that we want to shift the focus from description towards a normative point of view. Additionally, instead of basing our evaluation on a policy point of view, we want to take ethical considerations as the basis of our assessments.

An important choice in our approach is to view only humans as actors in a network. It is a major point of debate, especially in STS, whether non-humans should also be considered as acting entities in networks. We have chosen to disregard non-humans because we consider an equation of humans and non-humans both philosophically and morally dubious. Moreover, it seems that little explanatory power is gained by analyzing the role of non-humans in terms of deliberate actions instead of cause-effect relations. Hence, we will consider all humans who act deliberately and purposefully as actors. Groups and organizations that act deliberately and purposefully will also be considered actors, provided they are well organized and have mechanisms in place to make and express collective decisions.[15]

Another important question is how to draw the boundaries of the relevant network. In our view, what the relevant network is, will depend on one's explanatory and evaluative aims. We therefore draw the boundaries of the network pragmatically, taking these aims into consideration. This does not mean that we deny that the boundary of a network is sometimes a "hard" social reality for the actors involved. We recognize that sometimes actors who have a legitimate stake in an issue will not be involved in the relevant network. We call such actors stakeholders.[e]

Central notions in our network approach, in addition to stakes, interests, knowledge, recourses and power, will be 'problem definitions' and 'agendas'.'[17,18,19] 'Problem definition' refers to the different actor perceptions or interpretations of what is the central issue in the network. In our case, the various actors, for example, interpret the risks of GSBRs differently. We refer to these different interpretations as different problem definitions. From the definition of actors as acting purposefully and deliberately it follows that they have ends or goals. We take agendas of actors to be coherent sets of goals or ends, which these actors want to achieve. Different actors will usually have different agendas, i.e. differences of opinion about which issues should be addressed first in the network.

The differences in problem definitions and agendas among actors stem not only from differences in interests but also from what Grin and Van der Graaf call different 'frames of meaning'.[20] These authors localize such frames of meaning on two levels. The first is the level of the problem definitions of the actors given their goals and beliefs, and the second is the level of the empirical and normative background theories that lay behind these goals and beliefs. We will call the latter, second level, *the belief and value systems* of the actors, where belief systems refer to the range of theories and beliefs actors hold with respect to the way the world is. Value systems refer to the actors' convictions about how the world should be, including related normative and ethical theories.

We advocate an approach that starts with the messiness of the different belief and value systems of the actors in the relevant network. Value and belief systems are often not entirely actor-specific. They can also depend on the *role* of an actor in the network. In a research network, one can distinguish such roles as technological researchers, users and financers. Roles have been described as implying "a group of norms to which the holder of the role is supposed to subscribe." [15(p.84)] This means that actors with the same role need not have identical value systems but that the intersection of their value systems at least contains those values that are typical for the role they have in the network. It would be interesting to see whether actors in the research network with similar roles have indeed similar belief and value systems.

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e. Of course, the actors in the networks are also stakeholders, but not all stakeholders are necessarily part of the network. We use here a rather broad definition of stakeholders, i.e. a definition in which every actor that has a legitimate stake in an issue is seen as a stakeholder, independently of whether these actors have any actual influence (power) on the decisions being made, which is the main criterion for being part of the network.[cf. 16] We add the notion of *legitimate* stake because we do not want to see each actor that claims to have a stake as a stakeholder, even if we recognize that it is debatable which stakes are to be considered legitimate and which not.

4 BETTER UNDERSTANDING THROUGH NETWORK ANALYSIS

In this section, we apply the network approach to analyze the results of the GDR session. This will be done in subsection 4.3. First, in subsection 4.1, we identify the relevant network regarding the scaling-up of the GSBR technology, the GSBR network. In 4.2, we describe the roles, responsibility and agendas of the actors in more detail. After applying the network model to our GDR findings, in section 4.4, we pay attention to the added value of a network approach.

4.1 The relevant GSBR network

The description of the network is based on interviews, personal communications with the researchers, and reports produced in relation with the GSBR project. For agents to be an actor in the GSBR network they must fulfill three constraints. They must match the general definition of 'actor' in subsection 3.2; they can influence the decisions made and the actions undertaken in the scaling-up process; and they must have regular interactions with the other actors in the network. In addition, we distinguish several stakeholders not participating in the network, but who may undergo the consequences of decisions in the network without necessarily being able to influence them.

4.1.1 Actors

Based on the criteria mentioned, we distinguished the following five actors in the GSBR-network:

1) *The Kluyver Laboratory (Delft University of Technology)*, the biotechnology research group that initiated the research on GSBRs.

2) *DHV*, an international engineering and consulting firm with its main office in the Netherlands. *DHV* is responsible for carrying out the pilot-plant research; it does so in close cooperation with the Kluyver Laboratory.

3) *STOWA,* the Dutch consortium of water boards and other governmental bodies related to water management. *STOWA* financed part of the initial laboratory research on GSBRs and the pilot plant research.

4) *STW*, a governmental agency that stimulates innovative academic research and promotes the application of that research. It financed the GSBR-project related PhD research.

5) *Water Board Vallei & Eem*, a water board that accommodated and hosted the pilot plant in Ede. It provided the technical environment, such as sewage water pre and post treatment and a buffering facility for the researchers of *DHV* and the Kluyver laboratory to perform their measurement schemes. *Vallei & Eem*, however, was not actively involved in the enterprise of the pilot-plant research.

STOWA has installed a supervisory committee to monitor the progress of the GSBR project. Its members are researchers, water boards as being potential users of the

GSBR technology, and three engineering firms. The supervisory committee acts as a forum where actors from the network, and some from outside the network, meet to have discussions and make relevant research decisions. The supervisory committee is not an actor in the network. Although the committee has a decision-making procedure in place, it does so in the sense of providing a forum that is open for negotiations between the actors, instead of providing a generally accepted agenda.

We distinguished three kinds of relations between the actors.

1. *Information and knowledge sharing*. Most actors in the network mutually exchange knowledge and information via a supervisory committee installed by *STOWA*.
2. A relationship of *financial or labor input*. These relationships establish asymmetric bonds of dependency.
3. A relationship of *potential deals*.

The main outline of the network is shown in figure 1 below.

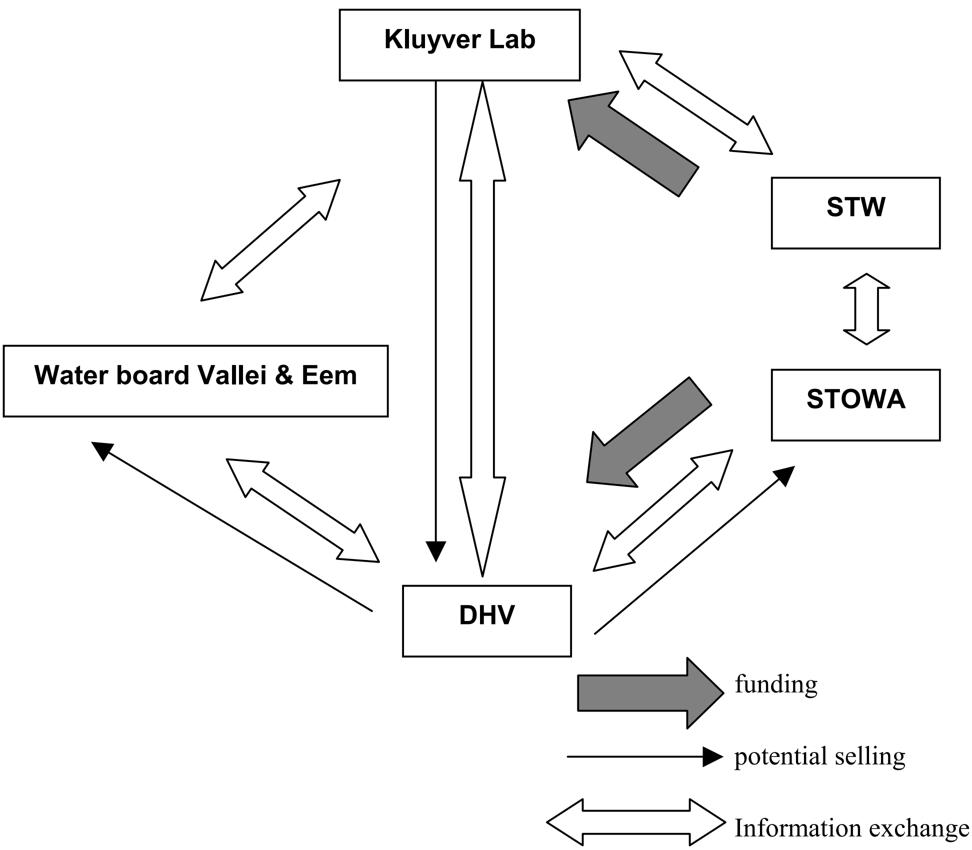

Figure 1. *Network GSBR development*

4.1.2 Stakeholders

Apart from the actors in the network, we also considered other relevant groups who do not participate in the GSBR network, i.e. stakeholders. In the first place, the new technology is relevant for the potential users of the new technology, viz. the water boards. In the Netherlands, the water boards are responsible for treating sewage up to a level that meets the primary effluent requirements. Another group of potential users is polluted water emitting industries. During the scaling-up process, the aerobic GSBR technology was advertised for industrial use, since industry, just like water boards, needs stable and cost efficient wastewater treatment technology. Other engineering firms constitute a third group of stakeholders. If the new technology turns out to be a success, it will be sold and possibly designed by these firms. The new technology might be interesting for governmental regulators, because it might be a means to achieve newer, stricter effluent standards. Launching the technology might also introduce new risks, which need to be regulated. Finally, the public can be seen as having a stake in the new technology. Most members of the public are in one way or another, 'consumers' of clean water, the product of sewage treatment. If sewage treatment is done inadequately, it may cause negative effects on human health and ecosystems. In addition, sewage plants may introduce specific risks for their employees and people living in the direct neighbourhood of the plant, for instance the potential health risks posed by the aerosols.[f]

4.2 Roles, Responsibilities and Agendas

Now that we have distinguished the main actors in the GSBR network, we will describe their roles, agendas and responsibilities in more detail. We will use these in subsection 4.3 to explain some observations we made in the GDR session.

4.2.1 Roles and responsibilities

We could distinguish four types of roles in the network that were being played by the five actors in the network. We distinguished between the roles of:

1) *researchers*, i.e. *Kluyver Laboratory* and *DHV*
2) *producers* of the technology. This role also included activities like design and consultancy, e.g. *DHV*
3) *users* of the technology, i.e. water boards especially *Water board Vallei & Eem*
4) *financers* of the research, i.e. *STOWA* and *STW*

The users of the technology, the water boards, are formally obliged to clean sewage up to the level of the primary requirements set out in Dutch and European law. These

f. Aerosols are very fine droplets of sewage water that, during aeration, are launched into the air; the wind can spread pathogens held in these droplets over several kilometers.

water boards also have to keep an eye on developments regarding secondary requirements, as, for instance, in our case, the MTR requirements (see footnote d). The responsibilities of the producers of the technology, the engineering firms, are enshrined in the contracts they sign with the water boards. Finally, it is a formal responsibility of *STOWA* and *STW* to spend the taxpayers' money in a justifiable way.

Besides the formal responsibilities, we also wanted to find out how the different actors in the network, whether tacitly or openly, allocated responsibilities informally to each other in the network. Such informally allocated responsibilities are relevant, for example, if unforeseen and undesirable consequences of the new technology materialize, which have not been accounted for in formal contracts or the law. If such consequences materialize, the actors in the network should have an opinion as to who, in the network, is to blame. In the next stage of our study, we will draw a map of such informally allocated responsibilities. Note, however, that the distribution of informal and formal responsibilities may be partial in the sense that all responsibilities need not be effectively allocated.

4.2.2 Agendas

Besides having different roles and responsibilities, actors also have different interests and aims. These aims and interests will have consequences for the choice of the issues actors want to address within the context of the network. In section 3, we have called these the agendas of the actors. Below, we will elaborate on the interests and aims of each actor in the GSBR case, and the consequences for their agendas.

The aim of the Kluyver laboratory is to do innovative technological research and to educate students and engineers. If this technology is successfully developed and patented, it will increase their status as an innovative technological research institute, which in turn will improve their chances when applying for grants. With respect to the GSBR scaling-up network, the following issues will be on the agenda of the Kluyver Laboratory: doing innovative research and publishing the results, developing the GSBR technology and acquiring patents.

It is the specific aim of *DHV* to develop the GSBR technology further and bring it to the market. The following are important issues on *DHV*'s agenda: developing the technology, bringing the technology to the market by selling it and providing consultancy, and acquiring patents.

DHV's agenda is in many respects similar to that of the Kluyver lab. *DHV* might find it prudent, however, to keep the development process as short as possible because it wants to bring the technology as fast as possible to the market. In addition, Kluyver has the drive to publish papers on the developments whereas *DHV* would rather keep the relevant engineering knowledge to itself. Consequently, the differences between the agendas of Kluyver and *DHV* may cause friction.

Let us now consider the agendas of the two financers of the GSBR development project. The mission of the *STW* is to stimulate technical and scientific research at Dutch universities and some selected research institutes, and to encourage third parties to apply the results of this research. Apart from stimulating research, an important item on the agenda of *STW* is therefore the development of new technology. *STOWA* is primarily a financing organization set up by the water boards and, therefore, developing new, efficient and robust technologies that can help to meet increasingly strict effluent requirements will be high on its agenda. This agenda fits well with that of the water boards as potential users, but may cause friction with the agendas of actors focused on scientific research.

Finally, the water board *Vallei & Eem* will be primarily interested in the GSBR technology as a means to achieve effective and efficient sewage treatment. Apart from that, it will try to score on the benchmark for Dutch water boards. One aspect of this benchmark is innovativeness, which may be a reason for the water board to facilitate the pilot plant research.

The different agendas of the various actors are illustrated in Table 2 (below). The table shows where the agendas of the actors possibly overlap and where tensions might occur. An "O" indicates that the corresponding item is on the agenda, whereas an "X" indicates possible friction with a corresponding agenda item.[g]

	Fundamental research	Stimulating research	Research & Development	Stimulating product development	Quickly launching GSBRs	Effective sewage treatment	Patents for Kluyver \DHV
Kluyver	O		O		X		O \ X
DHV	X		O		O		X \ O
STOWA				O		O	
STW		O		O			
Water board Ede						O	

Table 2. Agendas of the Actors; O means item is on the agenda; X means potential friction

4.3 Explaining the GDR Results in Terms of the Network Approach

We will now try to explain some of the observations of the GDR session using the GSBR network as explicated in subsections 4.1 and 4.2. We will focus on the following observations.

1. The different meanings attached to the notion of risk (4.3.1)
2. The differences in estimated probability of not meeting the primary requirements (4.3.2)
3. The differences in meaning with respect to notion of 'beheersbaarheid' (4.3.3)
4. The responsibility for preventing secondary emissions (4.3.4)

g. NB a "X" in the table does not emphatically mean that both parties involved will always hinder each other on the subject of the column. It only indicates a possible cause of friction.

In explaining these observations, we will limit ourselves to two actor *roles*: researchers and users. While some people, who could be classified under the actor roles of financier and of producer where present at the GDR session, on most issues we did not witness a clearly distinct perspective on their side. Consequently, in our presentation we will lump the producers (*DHV*) under the researchers and the financer (*STOWA*) under the users.

4.3.1 The perception and conceptualization of risk

A first issue is the correlation between the probability and the impact of an accident. For the users, this correlation was much higher than one would expect, whereas for the researchers, it was as low as one would expect (cf. subsection 2.3).

We may consider at least two different explanations. The first is to say that most relevant literature defines risk as the probability of an accident times its impact. Since it is a priori unlikely that in our case the probability of accidents empirically correlates with the impact of those accidents, the users' perception of the risks is mistaken. Furthermore, this would not be strange since the users are not used to tinkering with conceptually intricate differences between probability and impacts of accidents; moreover, perhaps they are not as sharp as researchers regarding theoretical notions. A second explanation points to differences in the belief and value systems of the various actors. It takes the outcome of the GDR to mean that probably for the users of the new technology, risk is not the probability of an accident times impact. A risk is a risk, it might be small and it might be large, the accident happens or does not happen, and we do not want it to happen. This risk conception serves a different goal than the one defining risk to be impact times probability. The first, and scientific one, serves the goal of a scientific analysis of risks whereas the second one concerns concepts of social acceptance and legitimacy of risks.[21] Consequently, the meaning of 'risk' for the users is not identical to the meaning of 'risk' for the researchers.

4.3.2 Meeting the primary requirements

The users were sceptical about whether aerobic GSBRs will meet the primary effluent requirements whereas the researchers were optimistic (cf. subsection 2.3). A prima facie explanation draws on simple laws of economics regarding sellers and buyers of commodities. An additional explanation may be found in the differences in formal responsibilities and agendas. Meeting the primary effluent requirements is a formal, i.e. legal, responsibility of water boards and, therefore, is high on their agenda. If a water board does not meet the primary requirements it may have to face fines or be held liable for damage. Consequently, water boards are often careful with the introduction of new technology and wait until the technology is proven and robust. It is probably for such reasons that water boards are usually seen as 'conservative' by researchers in particular. This at least partly explains why the users are more pessimistic than the researchers about the likelihood that the primary requirements will not be met.

4.3.3 The notion “beheersbaarheid”

That differences in roles, responsibilities and agendas tend to coincidence with differences in meaning attached to certain terms was also underlined by the observation that different actors understood the Dutch notion of ‘beheersbaarheid’ differently. As we have seen in subsection 2.3, the water boards thought of ‘beheersbaarheid’ as manageability. They were primarily concerned with the robustness of the treatment process such that fluctuation of the influent would not interrupt the process, potentially leading to failure to meet the primary effluent requirements. This way of conceiving ‘beheersbaarheid’ is understandable given their agenda and responsibilities. The technological researchers, in contrast, saw ‘beheersbaarheid’ as a scientific notion, i.e. whether the process is controllable in theory, by adjusting parameters, instead of whether it is manageable in practice. Again this fits well with the agendas and responsibilities of these actors. Difference in agendas and formal responsibility thus, at least partly, explain the different meanings that water boards and researchers attached to the term ‘beheersbaarheid’. The same kind of miscommunication is likely to occur when the parties involved, with different backgrounds and responsibilities, discuss the robustness or the stability of a system.

4.3.4 The responsibility for preventing secondary emissions

Apart from differences in formal responsibility, differences in informal responsibilities also exist in the network. Even if responsibilities are not officially allocated to any of the actors by law, contracts or explicit agreements, actors may feel responsible for certain issues or they may allocate responsibilities to others in the network. In our case study, a typical example is the risk of secondary emissions. Secondary emissions are not yet regulated, though it is likely that some current concerns with respect to secondary emissions in sewage treatment may in the future result in tighter official requirements; the MTR requirements serve as an example.

The way the actors allocate the responsibility for secondary emissions may generate a *problem of many hands*.[22,23] The term problem of many hands usually refers to a situation in which something undesirable has occurred, and in which pinpointing the responsibility for the undesirable event is almost impossible. This difficulty may be due to an initially unclear allocation of the responsibility, or to the fact that many individuals contributed to the undesirable event. In the latter case, finding out who contributed to what extent to the undesirable event might be difficult. Moreover, blaming people for their contribution may be unfair, if they were unable to foresee that their actions would contribute to the undesirable event. Here, we are concerned not so much with a problem of many hands in retrospect but with one in advance; no undesirable consequence has yet occurred; however, both, the researchers and the users dismiss responsibility for not meeting the secondary requirements.

4.4 The Added Value of Network Analysis

We have tried to make it plausible that the observations in the GDR session can be explained by looking at the different roles, responsibilities and agendas of the actors. Our findings clearly indicated differences in problem definition, semantics and responsibilities between actors with different roles, especially between researchers and users. These differences emerge with the semantic ambiguities with respect to the notion of risk, where a deep philosophical question about the conceptual interpretation of risk underlies the ambiguity in meaning. The 'beheersbaarheids' discrepancy is less important than the one of 'risk'. Although this conceptual discrepancy may be caused by a difference in value systems, the ambiguity can be dissolved just by convention. Whereas 'scientific understanding' and 'innovativeness' are important values for the researchers, the users seem to adhere to such values as 'stability', 'certainty' and maybe even 'conservatism'. Such value differences also partly seem to explain the different perspective on how promising this technology is for meeting the primary requirements. As suggested, the value differences may also be linked to differences in formal responsibilities. Our data thus suggest that researchers and users do have different value system and different conceptual frameworks. The differences in conceptual frameworks might be explained by differences in belief systems, i.e. by different background theories about reality. We did not find, however, any direct proof of differences in belief systems.

5 NETWORK ANALYSIS AS TOOL FOR DISCERNING AND ANALYZING ETHICAL ISSUES

We have presented network analysis as a theoretical background against which to interpret the results from the GDR session. Now we turn to the task of indicating the ethical significance of those findings. In doing so, we make clear how a network approach can be helpful in discerning relevant ethical issues in R&D. We do so in subsection 5.1. In subsection 5.2, we will address the question of how a network approach might be helpful in discerning and analyzing ethical issues, and in adequately dealing with them. We will argue that a network approach allows for ethical analysis and judgment without presupposing a shared belief and value system.

5.1 Network Analysis as a Tool for Discerning Ethical Issues

In subsection 2.3, we made four observations, which were further analyzed and explained with a network approach in 4.3. Here, we will turn to the ethical relevance of these findings.

The first issue concerns the different conceptualizations of risks by users and researchers. Questions about the acceptability of risks are generally considered to be ethically relevant.[1,2] The finding that users and researchers have different conceptualizations of risks that can be traced back to differences in value systems adds a new dimension to the debate. It raises the question regarding which conceptualization of risk is most appropriate in the discussion about the acceptability of certain risks. This issue is ethically relevant because different conceptualizations of risks will probably complicate the discernment of ethical issues.[24] For example, a conceptualization that defines risk as probability times effect does not focus attention on the distribution of risks and benefits, which might be an important concern in the acceptability of risks.[1,2]

The second issue deals with the difference between the users' estimations of the likeliness of meeting the primary requirements and that of the researchers. The differences in estimates are probably not due to insincerity, but to differences in expertise and responsibility. This finding is nevertheless ethically relevant, first, because all the people involved see *not meeting the primary requirements* as an important risk (cf. section 2). If the primary requirements are not met, moral values such as human health and animal welfare are at risk. A second moral issue raised by the differences in estimates is to what extent spending tax payers' money on this new technology is morally defendable. The degree to which this is acceptable will depend on the expectation regarding whether the primary requirements will be met.

The third issue concerns the different meanings attached to the notion of "beheersbaarheid". The importance of this semantic ambiguity is underlined by the fact that *controllability of the granule formation* was considered one of the most important risks. Apart from that, the different interpretations reveal different priorities for research. Whereas users want to focus primarily on controlling the process, researchers primarily aim at understanding it. This question of priorities is also ethically relevant because if the process is insufficiently controllable it will introduce societal risks, which might be considered morally unacceptable. Yet, it could be argued that gaining more insight into the technology is instrumentally and intrinsically valuable.

The final issue is the responsibility for secondary emissions. The researchers argued that prevention of undesirable secondary emissions was not primarily their responsibility because when attempting to get a new technology working, being too concerned with all kinds of secondary risks is not productive. Even if this were true, such an attitude introduces risks, especially if none of the other actors takes responsibility for preventing secondary emissions, as happened. From a moral point of view, this is problematic because it creates the potential for health risks for the public and damage to ecosystems. It is also problematic because the relevant stakeholders, the public, consumers, those dealing with ecosystem preservation, are not included or involved in the relevant research network. From a moral point of view it is therefore undesirable that it is unclear who is responsible for avoiding or reducing the risk of secondary emissions. The problem of many hands is therefore not just a practical problem or a problem of control. It is also a moral problem.[23]

Applying a network approach to our case laid bare a range of ethical issues that we probably would have overlooked if we had started with a theoretical philosophical analysis. This corroborates the hypothesis that such an approach enables us to raise issues, which are not, and perhaps even cannot, be seen by the actors, but will be recognized when the actors are confronted with them. At the very least, our approach makes it possible to discern ethical issues that would otherwise probably be overlooked, by the actors and philosophers alike.

5.2 Ethical analysis and judgment

We believe that the network approach has an added value in discerning ethical issues and for making normative judgments. Some philosophers might object that the network approach is built on assumptions that challenge the possibility of such ethical judgment. After all, as we have seen in section 3, network approaches reject the idea of a shared belief and value system. Does giving up such an overarching belief and value system not entail also giving up the ambition of making any normative judgments about the network and the actors within the network?

Abandoning an overarching belief and value system does not entail an all encompassing relativism, let alone subjectivism. We consider abandoning an overarching belief and value system to be primarily a methodological principle that can be helpful in uncovering agendas, and differences in semantics and belief and value systems. Moreover, this abandonment might be helpful in identifying the moral problems to which these differences may lead. Yet, one should not interpret this *methodological* principle as a claim that any form of belief or value system that we discover among actors in a network is, *by definition*, equally good.

Even if we, as analysts, refrain entirely from making judgments about actors in a network, this would not block all forms of normative or moral judgments. First, the actors in a network can formulate moral judgments about other actors and our analysis might help them to do so more systematically and thoroughly. Secondly, one could also apply procedural criteria to the normative analysis of networks. In the literature, several procedural criteria have been proposed, such as the criterion of *learning and reflection*, which implies that actors should mutually learn how to improve the development of the technology. In addition, they should learn about the desirability of the underlying norms and values.[20,25] Moreover, the actors should become reflective about the different roles the actors have in the network, and the desirable shape of the network. Another possible criterion is *inclusiveness*, which implies that all actors and considerations relevant for the central issue or problem in a network are included in that network.[h] On the basis of our analysis in this article, a criterion such as there should be *no gaps in the division of responsibilities* in the network could be added.

It has to be emphasized that such procedural criteria have some ethical substance, even if they are geared towards assessing the quality of the interactions in the network, instead of the outcomes of those interactions. The criteria assume, roughly, that promoting a learning process among the actors is possible and desirable. This learning process is likely to diminish the problematic differences in perceptions and belief and value systems, even if it will not make these differences entirely disappear. In this way, we may come up with proposals for improvement, which are recognized by the involved actors as useful. In other instances, our proposals may not be welcomed by

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h. We defend a coherentist underpinning of the two procedural criteria mentioned.[26]

actors within the network but by relevant stakeholders; proposals to solve the sketched problem of many hands with respect to the secondary emissions might be a case in point.

In short, abandoning an overarching belief and value system does not mean abandoning morality. Much remains to be said by ethicists and philosophers, which is also recognizable and acceptable to the stakeholders or the involved actors. We do not imply that unanimity among actors equals moral acceptability. Yet, we claim that mutual recognition of the legitimate differences in agendas, semantics and responsibilities, and the possible lack of inclusiveness of the network contributes directly and concretely to diminishing, or even preventing, moral disagreements and gaps.

6 CONCLUSION

Our claim in this paper is that a network approach is helpful in discerning relevant moral issues in R&D that might otherwise be overlooked. We have illustrated this with the help of a case study on the development of a new wastewater technology. In our case, the GDR session delivered some interesting results, and the interpretation of these empirical results using network analysis has uncovered some ethical issues and yielded fruitful ideas. The methodological principle of shifting the focus from an overarching belief and value system, to the perceptions of the actors in a network, leaves us with a wealth of material. Our approach can be used to pave the way to a normative assessment of networks of technological research and development based on normative criteria.

One case study hardly establishes the proof of our approach; yet, we think we have good reasons to expect that the approach will be more generally useful. The main reason for this expectation is that network analysis is a useful instrument to uncover differences in expectations, and belief and value systems, in cases where various actors influence the course of R&D, and different stakeholders undergo the consequences of these decisions.

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