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To Ayara

Acknowledgement

I am dedicating this master thesis to my daughter. I want to thank her for motivating me and giving me the strength to go after my goals and for being the biggest reason why I want the world to be a better place.

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List of Abbreviations

ANA	National Agency of water
APPs	Permanent protection area
BA	Bahia
BRL	Brazilian Real (currency)
CFT	Federal Constitution of labor
CIF	Inter-federal committee
CONAMA	National Council of Environment
CTI	Intensive care unit
DNPM	National Department of Mineral Production
ES	Espirito Santo
FEAM	State Foundation of Environment
IBAMA	Brazilian Institute of Environment and Natural Resources
ICMBio	Chico Mendes Institute of Biodiversity
IGAM	Minas Gerais State Water Agency
MAB	a group of the affected by dams
MG	Minas Gerais
MMA	Brazilian Ministry of environment
MPF	Federal Public Ministry
MPMG	Public Ministry Minas Gerais
OIT	International labor organization
PAEBM	Mining Dam Emergency Action Plan
PGR	Plan for risk management.
PT Brazil	Workers party
SAAE	Autonomous Service for Water and Sewage
Sisema	State Secretary of Environment and hydro resources
TTAC	Terms of Transaction and Conduct Adjustment
UCs	Conservation units

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Introduction

The day of 5. November was a tragic day for many people living in the Rio Doce river basin. The Fundao dam of the mining complex Germano, in Mariana, MG, Brazil, owned by Samarco, with president Ricardo Vescovi and controlled by the huge mining companies, the Brazilian one - Vale and the Anglo-Australian BHP Billiton (Samarco, n.d.-d), broke between 16-17 o'clock and had enormous impact on the whole valley of the Rio Doce down to the ocean, which would persist for many years to come. Millions of m3 being a by-product from the mining activity of the mining company Samarco, overflowed into the river and destroyed everything on its way. The dam breach completely destroyed a village and had an impact on many others. Part of the material losses are the 349 demolished houses and ruined infrastructure. Apart from the material losses, there were human losses as well, namely, 20 people killed. To that add up the destroyed the flora and fauna of the region and the polluted rivers Gualaxo do Norte, Rio do Carmo and Rio Doce. Hundreds of people were displaced. (MPF, 2016, p. 12-60)

The disaster is being pronounced by the US consulting company Bowker Associates the as the most colossal one occurred involving the mining industry, being the leader in three categories: 1). The volume of the tailings which came out of the dam being between 32 and 62 million m3 (MPF, 2016, p. 13), 2. The size of the impacted territory: 680 km along the river and 3. The proportion of the damage: between 5 and 55 billion USD. (Bowker, 2015)

The mining industry has a central role in the development of the state of Minas Gerais. There is located the so-called iron quadrilateral. It occupies the central area of the state, with the biggest population, including the capital Belo Horizonte and cities which exist only due to mining industry, such as Congonhas, Nova Lima, Itabira e Brumadinho, as well as Mariana and Ouro Preto, where mining first took place in Brazil back at the end of the 17th century. All of those mining cities share common issues, such as a displacement of whole communities, urban transformations, environmental deterioration and tailing dams situated close to the urban areas. Moreover, most of the above-mentioned repercussions have received the prior consent of the public power. (Ferraz et al., 2015)

In economic terms, 17% of the GDP of the state of MG is coming from the mining industry. Based on data of the Public Ministry, almost half of the Brazilian iron exports in 2014 were

extracted from the above-mentioned iron quadrilateral. This leads to very strong dependence on the mining sector not only from the side of the municipal and state governments but as well NGOs, environmental projects and cultural institutions which are also mainly financed by the sector. For example, the entrepreneur Bernardo Paz opened the Institute Inhotim, a museum of contemporary art in the old mines of his mining company Itaminas. The undertaking was fully financed by the mining sector, with Vale, the biggest mining company in Brazil being its biggest sponsor. Paz summarized very well the situation in Minas Gerais, stating: "Mining is the soul of Minas Gerais. The state is only what it is because of gold, diamond, and ore,". (Ferraz et al., 2015)

However, there is a great problem of control and surveillance of the mining companies. The state doesn't have the capacity to implement strict oversight. The public ministry of Minas Gerais admits that there are numerous proceedings filed by the population in every mining city with claims and concerns for eventual environmental damages. Moreover, the government, having its legislative and executive powers financed by the mining industry, neglected even the investigations of the impact of the mining activities over the historic region. (Ferraz et al., 2015)

There are dramatic examples of the devastating effects of the mining industries on the environment in the region as a result of the economic power of the mining companies over the institutions. One such is the open crater left in the park of Serra do Rola-Moça. The state had approved the exploration of the mine in 1990, without the company even presenting a technical project. The company doesn't exist anymore, the area is abandoned and the crater is still there. Another example for the mining controversies is the city Itabira, 100 km away from BH, where Vale was created in 1940 by the president Getulio Vargas, (privatized by FHC in 1997). The city acts as a laboratory of the exploration of iron ore on a large scale. It was one of the cities which gained the most income from the mining industry before, in 2015 pronounced the state of bankruptcy, provoked by the drop in the iron commodity prices. Now it is left only with the consequences of the mining industry, for the sake of which many districts were displaced. The most recent example is the district Vila Paciencia, where the mining explosions were often impacting the buildings, rocks were flying into the district. The company decided to ‘increase the buffer zone between the mine and the district’, therefore started buying out the houses in 2007. However, between 2014-2015 the process was slowed down and now from the whole district, there are only 29 houses left, isolated, surrounded by

empty lots which are a property of Vale. Many other cities in the iron quadrilateral are suffering as well from the devaluation of the iron ore. The export prices dropped from $101 per ton in January 2014 to $34 per ton in October 2015. The latter came as a result of the global commodity crises and the slow down of the economic growth of China. (Ferraz et al., 2015)

Below would be described how did the accident of Fundao dam evolve. Most of the information would be retrieved from Ferraz et al., 2015 if not stated otherwise since it was the most detailed source, covering the event all along the river. The following Fig.1. visualizes route of the mud wave

Fig. 1. The route of the mud (Ferraz et al., 2015)

The first village impacted by the mud and the one which suffers the most from the devastating effects of the dam breach is Bento Rodrigues. Founded in 18. Century, it was one of the first villages created as a result of mining activities, by a person called with the same name, coming from Sao Paulo, who found gold in the area and started exploring it. The village with such a long history and historic importance was washed out by the mud wave in no time and was converted into a 'museum of mud' with personal belongings and photos mixed with the debris of the tailings spread over the area of what was once the village. (Ferraz et al., 2015)

The village was situated only 6km away down the hill for the Fundao dam (Carmo et al., 2017, p.147) was totally taken over by the mud. Important is to have in mind that the Fundao dam was situated 1200m over the sea level (Justica Global, 2016, p.3). The mud wave reached the village of Bento Rodrigues in only 11 Minutes so whoever heard the noise from the beginning on, had only 11 Minutes to save his life and alarm his family and neighbors. There was no sound alarm installed to warn the population (Justica Global, 2016, pp. 10-11.). According to the Public Ministry, the mud was at least 32 million m3 (MPF, 2016, p.12), but having in mind that 56 million m3 was stored in that tailing dam and during the accident, the dam was completely destroyed and the whole content flew out, probably the second number is closer to the truth. (Russau, 2017)

One of the inhabitants of Bento Rodrigues, Paula Geralda Alves explains in the media how she heard on the radio of her work colleague about the occurrence and went on her moped screaming on the streets that the dam has broken in order to inform the inhabitants of Bento. After she took a truck and took on it people she saw on the way and drove them to the hill. From there they all saw the dramatic scene of the mud wave taking over the village.
When the wave attained the village, it took the lives of 19 people and one unborn (MPF, 2016, p.56), ripped trees, destroyed houses and infrastructure, walls, the vegetable gardens and swept away the animals. (Bragon, 2015)

Fig. 2. Bento Rodrigues after the Fundao dam breach (Ferraz et al., 2015)

According to many of the former inhabitants of the village state that the mining company, Samarco was already a long time planning to acquire the territory of the village in order to 'increase the security of its operations'. However, when contacted directly, the company didn't comment that statement but merely mentioned that a couple of years ago it bought some lots with the purpose to plant trees for the future reforestation in support of its environmental conservation plan. (Ferraz et al., 2015)

After the mud wave left Bento, it damaged severy the rural district of Paracatu de Baixo, on the way down on the river Gualaxo do Norte. In the municipality of Barra Longa, which is 60 km away from the accident point, the above-mentioned river meets river Carmo. This encounter added up force to the force of the mud wave and the result was dramatic. Many bridges, houses, and farms were destroyed, tens of riverside houses were left abandoned. The mud was reaching 1 m of height. There were no human fatalities there, however many animals were killed. The mud reached here, 14 hours after the accident had occurred. Nevertheless, the population claimed that it was not been alarmed, otherwise, they could have saved many belongings and documents in that time, reducing the impact (Justica Global, 2016, p.3.). Another important impact that was felt later is that the mud killed the predators for the mosquitos transmitters of yellow fever. (Gomes, 2016) Some mention that there were some rumors about the dam breach already, but the people were expecting merely eventual overflooding, but nothing compared to the actual impact. There were as well some people in the impacted areas who were refusing to leave their homes and animals and were staying isolated there, but in the end, they were giving in and were also lodged as the others affected in hotels. (Ferraz et al., 2015)

After that river keeps its course downstream the Gualaxo do Norte river towards the municipality Rio Doce with a population of 26 000, 91 km away from Mariana. The wave reaches there in the morning about 7 o'clock on 6.november. Here as well the people were not officially informed but had already heard the rumor of the dam breach and many were gathered on the entrance of the city. In this point, the river of Gualoxo do Norte, has joined its water not only with the river Carmo but as well the river Piranga so the power of the mud wave has been multiplied. Moreover, the wave was also sweeping away it itself everything that comes in its ways, such as trees, cars, houses, the ripped parts of the riverbanks and the dead bodies of animals and human, which also increases the destructive power. Due to this

power, the mud wave firstly hit the hydroelectric plant, Risoleta Neves, operating in the municipality, managed in a consortium, having Vale as one of the associates, but there was such a strong clash that the water mixed with the tailings returned a couple of kilometers back from where it came and then hit again the hydroelectric plant. (Camara dos deputados, 2016, pp.117-118) There were many concerns that the plant won't be able to resist and would break as well, but fortunately, it didn't occur. It, however, recollected most of that wreckage swept by the river. In this area later were found at least 6 bodies, being swept with the water the whole way from Bento Rodrigues. Most of the bodies were found not found entire but just different parts of them, with exception of the body of the 7-year-old, Tiago Damasceno Santos. (Ferraz et al., 2015)

The city of Rio Doce was financing its activities mostly with livestock and the operation of the hydroelectric plant. After the disaster, the hydroelectric plant was stopped of operation, which led to losses of the municipality. The wave had a huge impact on the agriculture and animals raising activities as in the other places as. However, the biggest impact the city suffered was related to the wreckage, namely as already mentioned everything that the river brought on its way, was stopped by the hydroelectric plant and after the disaster, there were extensive and expensive clean-up actions to be taken. Moreover, there were many concerts for impact on the human health of this pollution. The company declared that it will conduct the cleanup operations in the city and in the neighboring municipality Santa Cruz do Escalvado, however, the area where the wreckage was to be transported to was not yet defined. (Ferraz et al., 2015)

The mining company Vale was also dropping part of its tailing in the Fundao dam. It is co-responsible for the dam breach and the consequences from it. It is, however, ironic that the so-called Steel Valley, Vale de Aço, where the steel production takes place and has a participation of the mining company Vale, located about 150 km from the municipality Rio Doce, it was not impacted by the suspension of the water supply. (Ferraz et al., 2015)

Further on the way down, 3 days after the dam breach the tailings reached Governador Valadares, 300 km away from the point of the accident. It is the city with the biggest population, 300 000 inhabitants, which depend on Rio Doce for its water supply. Before the event, the water supply of the city was already problematic due to the low of precipitation that season and due to the lowered water level of the river. However, after the arrival of the mud,

the water supply was completely suspended for 9 nine days. Distribution of mineral water was organized by the company and the state. The lack of water provoked conflicts. On one hand, there was a lot of tension created among the victims waiting in those queues. The conditions were also very stressful. The waiting time could get to 2 hours under the sun, at a temperature of 40 degrees. Moreover, there were cases of water merchants increasing the price of the water with 100% and even some water supply trucks which brought the water to the supermarket for sale. Pastor Flamarion Rolando, also assisted with the water distribution, distributing water coming from donations from other churches. He was criticizing Samarco for not delivering the water to the homes of the affected, spearing the whole stress and conflicts around. According to information from Samarco until 28 November the company has provided the city of Governador Valadares with more than 43 million potable water and more than 5 million mineral water. In relation to the distribution of the water Samarco is putting the responsibility on the state civil defense, which from is turn claims it is a responsibility of the municipal civil defense. (Ferraz et al., 2015)

Later, the state with the support of Samarco and the state technicians started pumping out water in order to recover the water supply of the city. The city's water supply was restored to a major extent, 70-80% until the end of November, according to the municipal company engaged. However, that water was with highly increased turbidity, 2000 NTU, still lower than the initial level of 3000 NTU in the day of the arrival of the mud, but much higher than the normal level of 300, according to information given by Mário Nunes, manager of the water treatment production of the SAAE (Serviço Autônomo de Água e Esgoto). Moreover, the water had a very strong specific smell as a result of the chemical products used to treat the water. According to the tests requested by the public ministry, the water treated by SAAE didn't contain heavy metals and was not bringing risks for the human health. Using that argument the secretary of education imposed the tap water to the children in the public schools prohibiting them to drink bottled water. However, the public ministry argued that such kind of imposition is a violation of rights and allowed the parents to provide their children with mineral water. (Ferraz et al., 2015)

The suspended water supply affected many small cities which depended on Rio Doce. The case of Colatina, Es is similar to the one of Governador Valadares. In addition to the other issues, there were complains of the population to have suffered from diarrhea and skin

irritation after the use of the water, which increased the concerns about its portability. (Ferraz et al., 2015)

After Governador Valadares, the mud reached the municipalities Galileia (MG), Aimores (MG) and Baixo Guandu (ES). In these places, the impact of the mud was mostly over the fishing activities and the agriculture. (Ferraz et al., 2015)

The fishing activity in Rio Doce was completely suspended after the Fundao dam breach. About 9 million tones of dead fishes were found on the riverside (Justica Global, 2016, p.3.). For the fishermen was already clear what is to come because they were having already the historical experience with accidents and compensation. In 2005, due to the operation of the hydroelectric plant in Aimores, the watercourse of the river was changed, which impacted severely the water quality and the amount of fish. As a result, hundreds of fishermen living in the municipalities Ituêta, Resplendor e Aimorés, e de Baixo Guandu in MG were waiting for 10 years for financial compensation. According to Leci Estevam Pereira, professional fishermen for 20 years and president of the fishing association of Aimores his catch had then reduced to one third. As a compensation, the Aliança Energia, a consortium of Vale (55%) and Cremig (the energy company of the MG government) signed an agreement with the public ministry that they would pay 123 fishermen a minimal salary plus basic food corb. Nevertheless, those fishermen could still keep on fishing until the day of 16 November 2015 when the tailings from the Fundao dam reached the area situated 370 km away from the epicenter. (Ferraz et al., 2015)

Even though 123 fishermen were to be compensated, there are many more who depended on the fishing as a source of sustenance. Many of those who are registered as professional fishermen were still refused compensation. Therefore, they filed individual law cases. On the top of that, the company didn't stick to the agreed with the public prosecutor to conduct courses for professional reorientation of the fishermen. There are also disagreements related to the value of the compensation. The fishermen insisted that the company pays them compensation equal to the average of their income before the Aimores hydroelectric started operation or 2,5 minimal salaries. In 2015 a new case was filed by the public prosecutor office against the company to pay BRL 50 million for moral damages and BRL 90 million per each of the 123 fishermen as a compensation of breaking the fundamental human rights of work and human dignity. The only comment given on the case was from the side of the plant

management that they are developing environmental and social programs with respect to their environmental licensing. (Ferraz et al., 2015)

The case of the dam breach in Mariana is even much more complex and more impactful than the one in Aimores and completely put an end to the fishing activities and to sources of income of many people. Now the biggest concern is how the multiple different groups of victims would be compensated. Benilde Madeira is one of the many fishermen, who are officially registered as professional fishermen and still were not included in the group of the people who receive indemnization related to the accident in Aimores. Based on that experience he says that he would rather negotiate with Samarco now than go to justice. He says that he has to accept whatever the company has agreed on with the governments than live again the same troubles he did the previous time. (Ferraz et al., 2015)

The other biggest impact the city of Aimores suffered after the accident is the one on the agriculture. There were 14 thousand heads of livestock which used to drink water from the Rio Doce, for which new solutions has to be found. A slaughterhouse even refused meat from cattle pasturing close to the river due to possible contamination of the meat and the milk. Some of the farmers sold out their animals, like for example the young farmer Bruno Cardoso, 23, from the rural area of Galileia municipality, 50 km away from Governador Valadares with a population of 7 000. He sold 25 animals in order to invest in a well on his property for the irrigation of the sugar cane and the fruits and vegetables he has planted, which were formerly as well irrigated with water from the river Doce. There are millions of people who were sustaining themselves with agriculture and were affected by the tailings of Samarco. They are assembling in syndicates and associations in order to make Samarco and its mother-companies pay for their losses. Others such as Bruno, file independent law cases. In his case, he required compensation for the well he installed, with a value of BRL 20 thousand reais and for the fence he has to build so the animals he was left with don't have access to the water of the river. With the indemnization, he would buy again his cattle and will pay back the money he lent from the bank for the above-mentioned works. (Ferraz et al., 2015)

Finally, the mud reached the region of the river mouth of Rio Doce, including the cities Linhares and Regencia, 670 km away from the event. The mud reached the region on 21. November 2015, 16 days after the dam breach. As a result of the wind and the waves, the mud spot in the mount of Regencia was growing and expanding offshore the sea. Every day

there were helicopters following how the situation was evolving. According to data from the ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade), the spot had reached a size of 50 km already in the first days of December. (Ferraz et al., 2015)

Regencia is a small village, with about 1000 inhabitants. The population there was principally involved in fishing and in the last years also ecotourism thanks to its semidesert beaches, good surfing conditions and the nice islands and lakes formed by the river. The mud arrival changed it all. The fishing activity was suspended completely and the fishermen left without a source of income. Therefore, the president of the association of the fishermen of the region, Leônidas Carlos, came up with a proposal that the fishermen get involved in a post-disaster recovery of the river. The major portion of them did start working for Samarco, supervising the last part of the river. There, on the two sides of the river were installed buoys to protect the fauna and the flora on the coasts. The fishermen were paid BRL 150 per day which is much less than they would have earned fishing but still, there are happy to be able to be involved to help the recovery, have some source of income and not be left without any occupation. In terms of tourism, after the disaster, the inns got occupied by scientists, environmentalists, people working for Samarco on the recovery, pilots of helicopters and many researchers. (Ferraz et al., 2015)

Next, to the beach of Regencia, there is the environmental reserve, Camboios, which is also one of the bases of the Tamar project, dealing with the preservation of marine animals. The area where turtles were laying their eggs was transferred to another local further from the river and the animals are being observed. The area turned into an important spot to study and search for solutions for the mitigation of the disaster's impacts. An interesting fact is that the mortality of the fish in the area is not as high as the one in the other parts of the river, impacted by the mud. The suggested reasons are that the contamination is lower since the tailings are more diluted in the water in the mouth of the river due to stronger flow and therefore more oxygen for the fish. The strongest impacted were the crustaceans and the seabirds. (Ferraz et al., 2015)

After the disaster on the affected areas there were many volunteers from the churches and the universities, however, criticized was the support from the side of the federal power. One of the critics was that not much was done to support the victims one month after the disaster

regardless of the scope of the event and that the that the president Dilma Rousseff announced that there would be a financial support to the victims. Other critics were that the representatives of Ibama were not so much present; that firefighters, police, and agents of the municipal and state civil defense were in the local, they are mostly using facilities of Samarco, for instance, cars for transportation. Further, was criticized that the presence of federal representatives is very low in the area close to the accident and absolutely absent further on. As well was commented that many roads which were destroyed could be easily repaired but the public power was lingering to do it. (Ferraz et al., 2015)

The Union, on the other side, insisted that they closely following the events and are preparing together with the municipal and state governments of MG and ES a civil case against Samarco and its controlling companies Vale and BHP Billiton, requesting the company to pay BRL 20 billion for the damages. That it is represented in the emergency actions by the forces of the national civil defense and the armed forces. The military was first focused in Mariana and then later was sent to the other impacted places to take part in the water distribution actions. In the post-disaster phase, the federal government has assisted the Brazilian Geological Center, ANA, DNPM, and Ibama, and sent a list of the representatives who supported the action on local in Minas Gerais and Espirito Santo, that being 37 employers without counting the ones working in the headquarter in the capital Brasilia and the offices in Belo Horizonte and Vitoria. (Ferraz et al., 2015)

In summary, the disaster started at Fundao dam in Mariana, located 1200m over the sea level giving the tailing unimaginable power due to the gravity. First is flowed in the river channel of Rio Gualaxo do Norte, then the water mixed with the tailings made its way to the channel of the Carmo river (55km) and after another 22km it reached Rio Doce. Later, it flowed through the open sluice gates of the hydroelectric plant Risoleta Neves (Candonga) and on 22. November reached Regencia on the mouth of Rio Doce with the Atlantic. (MPF, 2016 p. 13) The river cross 228 municipalities and the population of the impacted region is 3,5 million and there is no clarity how long exactly would be needed for the recovery of the river and the local economy in the all the impacted regions (Camara dos deputados, 2016, p.18).

Theoretical Background

Disaster Management

In the chapter below would be used information retrieved from the UNISRD guidelines, the book about the catastrophe management of Jachs (2011), the book about the basics in the Civil Defence (2014) and the Introduction in the Disaster Management book by Coppola (2014).

The importance of the Disaster Risk Management is increasing due to the rising number of disasters happening all around the world. Disaster risk management is a part of the general Risk Management of a company. According to the ISO 31000, it is an agile process which should be repeated many times, adjusted and improved and that should happen on a regular basis (Jachs, 2011, p.93). Important guidelines about Disaster Risk Management are the Hyogo Framework of Action (HFA) (SEDEC/UFSC, 2014, p.47; UNISDR, 2005) and Sendai Framework of Disaster Risk Reduction (UNISDR, 2018b, p.2) from the United Nation Office for Disaster Risk Reduction (UNISDR).

In general, the risk management plan involves various participants, namely Civil Defence, Fire-fighters, emergency health services, ambulance, Military Police, civil organizations, the Red Cross and entities specialized in emergencies related to the electricity, transport, communications, and others. (SEDEC/UFSC, 2014, p.49)

The actions involved in the Disaster Risk Management could be divided into groups depending on the timely relation with the disaster, namely as actions for 1) preparation; 2) prevention and mitigation; 3) response and 4) recovery (Wegner, 2015). This is visualized in Fig.3. below.

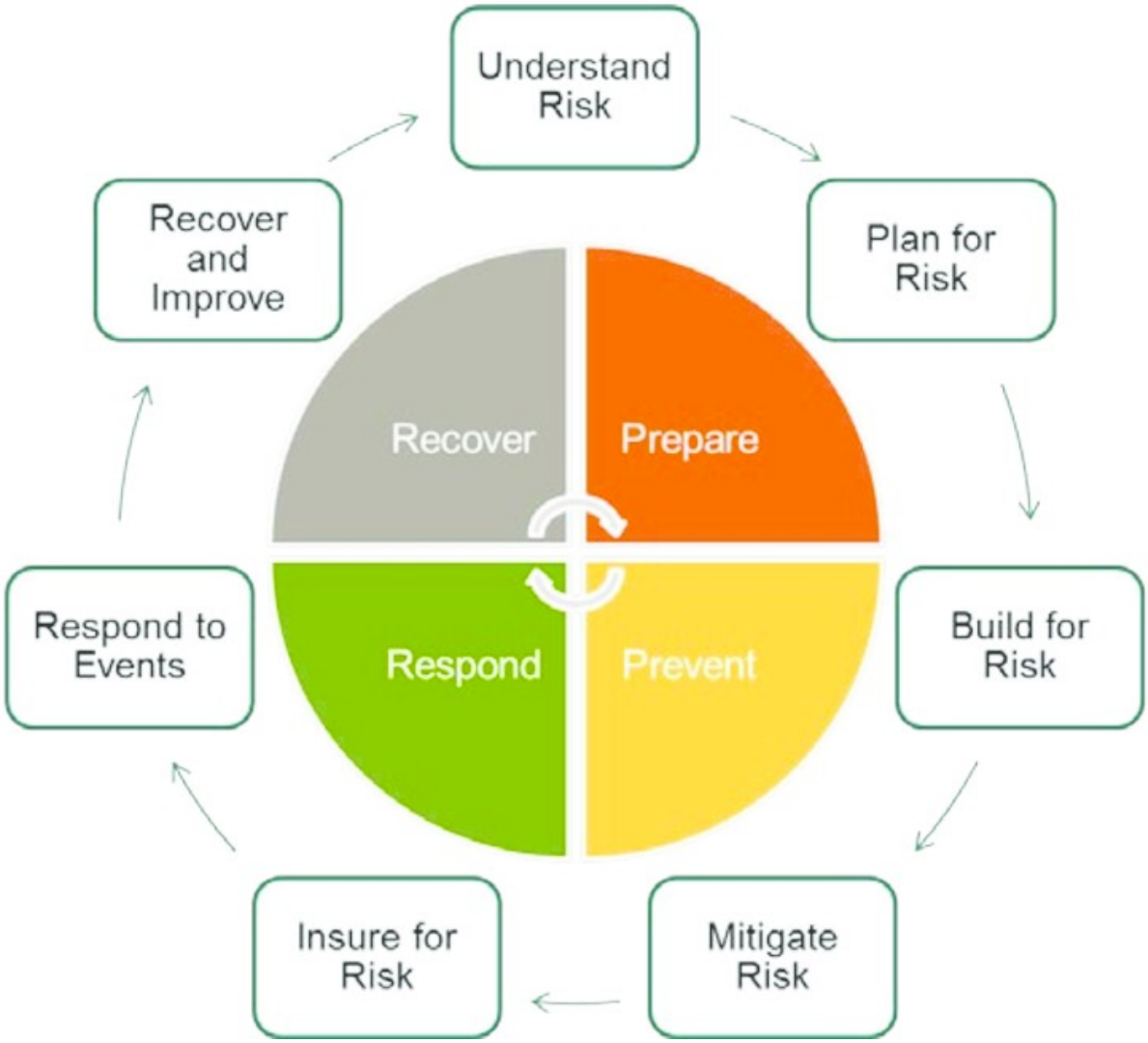

Fig. 3. Disaster risk management process goals (Suncorp Group, 2016, p.13).

The first two take place before the disaster happens, the third during and shortly afterward and the recovery is a post-disaster action. Below would be presented shortly each of them.

The first phase the Preparation occurs before the disaster, including setting the context, identifying the risks and assessing them. In order to lay the ground for the emergency response plan, first should be understood its importance and setting the context. In that sense, a team to elaborate the emergency plan is chosen and responsibilities are being allocated. Then is set the time plan for the draft of the plan, examination, and revision. Further, the methodology, the resources, and documentation to be used are defined (Jachs, 2011, p.95).

Below in Fig.4. could be seen a well-presented overview of the Disaster Management process apart from the fact the response phase is named ‘event’.

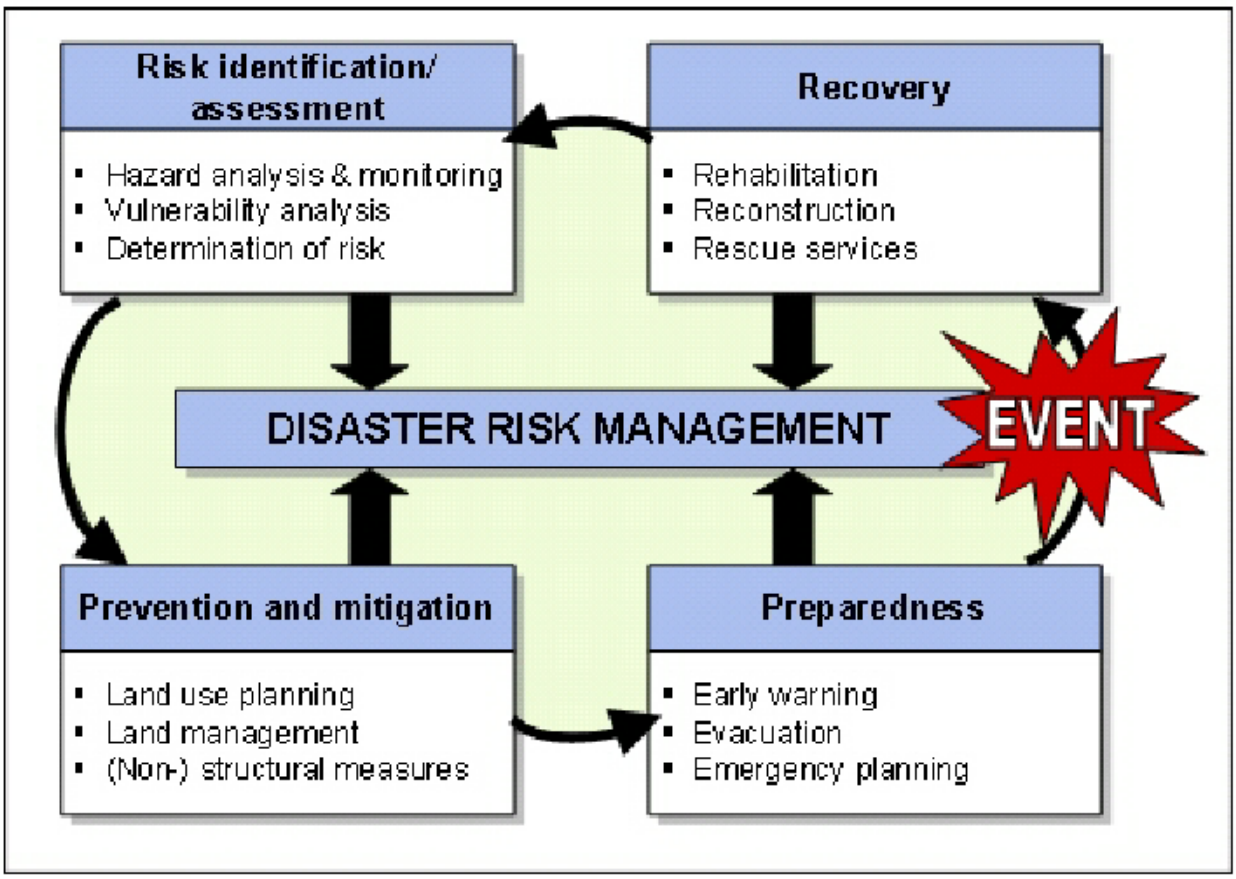

Fig. 4. Detailed Disaster Risk Management Prozess (FIG, 2006)

Risk identification

After all of this issues are concretized, comes the time for risk identification. First, all the possible risks and hazards should be outlined. After, possibly reasonable scenarios are being elaborated for each of the risks and are evaluated based on their occurrence probability and the size of their eventual impact. Not to forget are also the secondary risks which might be provoked by the primary ones. The identification of the risks can happen by different means, namely brainstorming, consultation of newspapers, historical reports of the company, reports from other companies in the industry or any other documents which could bring useful information. Moreover, in order to make sure that nothing is left out could be used checklists and risk catalogs which contain a list of risks. It is advisable that it is conducted during

workshops with as wide as the possible participation of different actors since they together would have a wider pool of ideas about risks (Jachs, 2011, p.97).

Risk assessment

After the risks are being identified, the next step is the risk assessment. It starts with hazard assessment, namely to find out additional information like the frequency of occurrence, in which season exactly, with which extend and what is the size of the impacts of the already identified risks. Then a vulnerability assessment is conducted, which points out which are the vulnerable elements if the risks already identified take place and why. Also, the degree of this vulnerability is analyzed. Such elements are people, buildings, resources and facilities which could be possibly impacted by the risk. Next, a capacity assessment is made, where is identified which are the resources which could reduce the impact of the disaster and how. Those could be either material ones or personal characteristics, such as expertize. The last is to examine the people's perception of risk in relation to possible risks occurring. (Coppola, 2014)

The next phase is the risk evaluation, which should be based on the most reliable information on hand, which might be quantitative data or based on experts consensus. There are different tools for that. One is the risk matrix, where the risks are plotted as a function of the probabilities and impacts. It is however problematic with an event with colossal probable damage but with a small propensity of occurrence(Jachs, 2011, p.101). Again it is important not to forget the secondary damages caused by the domino effect. In such case could be used bow-tie diagram or mistake tree analysis (Reniers et al., 2013, p.213). Also, a scoring model could be used, especially if a risk triggers various outcomes. However, regardless of which instrument has been used the evaluation should be easy to understand and to be able to be monetarized and objectively measured (Vanini, 2012, p.160).

Later, the disaster management team had to decide which risks are acceptable and which are not. For the second category, the team should search for solutions which eliminate the risk or at least reduce its impacts. If those solutions are implemented depends on the cost and benefits. Some risks might be easily and cost-efficiently eliminated and others might be too costly to do so. There should be as well priority ranking assigned to the risks depending on

the level of their unacceptability. Special attention should be paid to the risks which can not be eliminated in any way. (Jachs, 2011, p.102)

The idea of the all that extensive risk analysis described above is to be able to best allocate the available resource during the prevention and mitigation phase. First should be invested in the risks with a high priority of unacceptability. Therefore should be answered to the following questions:
Which of the risks has the most severe damage/impact? Which of the risk should be handled urgently and which have no time restrictions? Which risks are growing with the time and which stay the same? Which are the risks which are politically, economically and socially the least acceptable? And by which risks are the mitigation actions likely to act faster and by which slower? It is essentially important that this risk analysis is repeated many times on a regular basis so any new or missed out risks are taken into account. (Jachs, 2011, p.103)

Some of the risks might never be able to be mitigated. In this case, the burden of a risk possibly occurring could be outsourced to an insurance company or to public risk funds. (Jachs, 2011, p.105)

The work that the company has put in the risk management process up to this moment would be used as a base for further implementation. During the prevention and mitigation stages, the focus is on eliminating risks or at least mitigating their impacts. This includes enforcing the landscape so landslides don't occur, clean up the riverbed so there are no floods during the rainy season. In general speaking, any ‘structural or nonstructural measures’ diminishing the impacts of the risks or the risks themselves. (SEDEC/UFSC, 2014, pp.54-55)

After the prevention and the mitigation comes the preparation. Since the risk is a factor of a threat and vulnerability and is unlikely to be able to influence the treat, the only way to reduce the risk is by reducing the vulnerability (SEDEC/UFSC, 2014, p. 73). According to UNISDR the main focus of that phase is to take actions to prepare by improving the capacity in order to be able to face an eventual disaster. Examples for preparatory measures are to install a warning system to allow faster evacuation, train the population how to act in case of emergency and make simulations, make a stock of equipment and provisions like food and water and not the least es establish and maintain communication on an effective level, since that could have a crucial role in the case of an emergency. New facilities could also be built,

however, the focus is on expanding the awareness and understanding of the population and their knowledge of how best to deal with the situation, therefore training and education have a central role. For instance, if we take the example of the warning system, the people should be able to recognize it, be aware of what it means when it is on and what they should do. It is a way to transfer information very fast and alarm the population of the risk giving them time to react. That time could be often crucial in that situation and could reduce human deaths and environmental and material losses. (SEDEC/UFSC, 2014, pp. 55-57)

All of the steps above occur before a risk materializes itself. When however the risk occurs it comes the time for the response. It includes action during the occurrence and right after it. In that phase, it is a matter of saving lives, safeguard from harm, provide the necessary to the affected and limit the negative impact. Often it is hard to differentiate between that stage and the one after since although this one aims only the short-term solution of the situation, like drinking water distribution, food, and temporary lodging, some of the actions continue further.

According to the act 7.257/2010, the actions being part of the response stage could be divided into 3 categories:

- Emergency actions: save the lives of people, rescue actions, first aid, assist the people until they reach a hospital etc.
- Assistance aid: assist people by providing them with drinking water, food, shelter, clothes, personal hygiene products, managing the death bodies etc
- Re-establishing the public services for communication, transport, electricity, drinking water, sewage, ensure damage buildings and clean up after the disaster so to ensure the safety of the area. (SEDEC/UFSC, 2014,pp.57 - 58)

The last stage of the emergency plan begins immediately after the response stage and has as an essence to reconstruct public infrastructure in a sense of roads, buildings, dams, water supply system etc. The aim is to recover the previous to the disaster state. The UNISDR highlights that the actions should be conducted so that the risk of future similar events is reduced. This stage as well should be based on priorly defined strategies so that the least time is lost and everything comes again back to the normal and to make it easier and more straightforward to the population to take part in this process. (SEDEC/UFSC, 2014,p. 58)

According to the National Plan for Civil Protection (Plano Nacional de Proteção e Defesa Civil, (PNPDEC) it is a responsibility of the state, municipality, the Union to reduce the disaster risk (SEDEC/UFSC, 2014,p. 59), therefore they have to insist on good elaborated disaster emergency plans from the companies and be very strict in the monitoring. They should also give priority to displacing people living in high-risk areas.

As final remark would be left the definition of the UNISDR that an event is not a disaster per se, but rather it turns out to be one when the risks are managed poorly and there is not sufficient capacity built in advance so that the impacts are smoothly dealt with.

Precaution

In the current times, there is a constant increase in technical and technological development. Due to that activities with increased complexity could be performed. However, that brings along many risks and uncertainties. In order to prevent for the negative consequences related to those risks and uncertainties, precaution should be taken. Indeed, more research is needed so the understanding is increased and the uncertainties reduced. However, for the time being, it is essential to take preventive measures so the impact of eventual hazards could be reduced or completely phased out. On those foundations lies the precautionary principle. It is in a sense an alternative to the conventional risk assessment, which turns out not to be very precise when uncertainty and ambiguousness come into the play. (Raffensperger et al., 2014, pp. 3-5)

The reason for that is that the risk is a function of the consequences of events that might occur and the probability for that happening. However, both of these parameters could be separately or simultaneously uncertain and ambiguous. (Stirling, 2007) For example under the condition of uncertainty, the eventual results could be predicted but not the probabilities of them occurring (Finetti, cited in Stirling, 2007); under the condition of ambiguity, it is the other way around: the probabilities could be defined but not the possible outcomes (Wynne, cited in Stirling, 2007) and finally under the condition of ignorance, neither the outcomes not the probabilities could be foreseen (Collingridge, cited in Stirling, 2007). These different states of incomplete knowledge are visualized in Fig.5. below. In the last category fall the most environmental issues.(Funtowicz et. al., cited in Stirling, 2007)

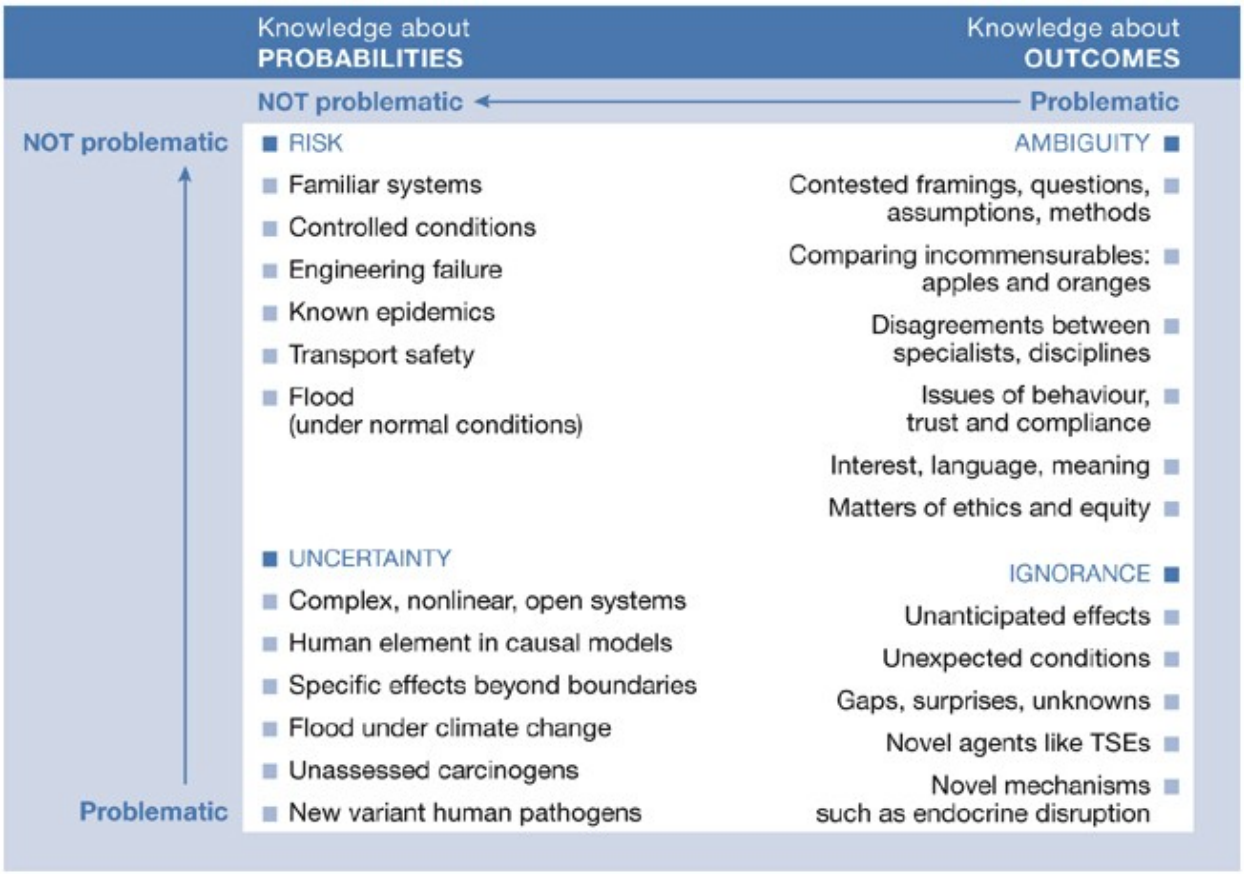

Fig. 5. Four states of incomplete knowledge (Stirling, 1999)

Hence, even though the risk assessment provides in an elegant way straightforward information, under the conditions of uncertainty, ambiguity or ignorance its use is not suitable. It is where the precautionary principle is a solution. Nevertheless, the methods offering a solution under the above-mentioned conditions should be seen as complementary to the risk assessment, rather than replacing it (Stirling, 2007)

There are no strict rules when it comes to the precautionary model, but rather general guidelines giving an opportunity to the decision makers to search for alternative actions making the best use of the information they have. Therefore, the actions taken would depend on the individual situation. (Raffensperger et al., 2014, pp. 3-5)

The emergence of tools such as the precautionary model has been provoked by the inability of the currently used tools and methods to solve the complex issues arising nowadays. The contemporary approaches to risk evaluation are reactive, focused on the consequences of a trigger and probability, rather than being actively looking for alternatives. Moreover, there is a notion that if risks are not able to be identified or quantified they are not present. Not to

mention, that many activities pose a risk of long-term negative impacts, but until the latter is confirmed, no actions are taken. However, when being confirmed it might be too late already. (Martuzzi, Tickner et al. , 2014, p.8) Another reason is that issues such as the climate change are being resolved way to slowly in comparison to their evolution progress, therefore the capacity to be controlled is being doubted (Kiebel et al., 2014, p.147).

Hence, the precautionary principle was born. Its essence is that cost-effective precautionary measures should be taken if there is a doubt that an activity could impair the human health or the environment, even without a firm scientific proof (UN, 1992). Vorsorgeprinzip is the German term, from which originated the name in English and it brings the idea about actions to take in anticipation, rather than as a reaction to something. It has been used as a cornerstone in the European Union environmental laws. (Kiebel et al., 2014, p.146) It is seen as a way to responsibilize the ones provoking the hazard.

As was already mentioned precautionary principle should be seen as a complement to the risk assessment. That way could be made an use of the advantages proposed by the two methods. Both could be combined in a process, in which first the attributes of the risks are examined for any kind of uncertainty and ambiguity and if there is no such identified, the conventional risk assessment is to be used. On the contrary case, the precautionary principle is to be implemented. (Stirling, 2007) Fig. 6. below visualizes the process.

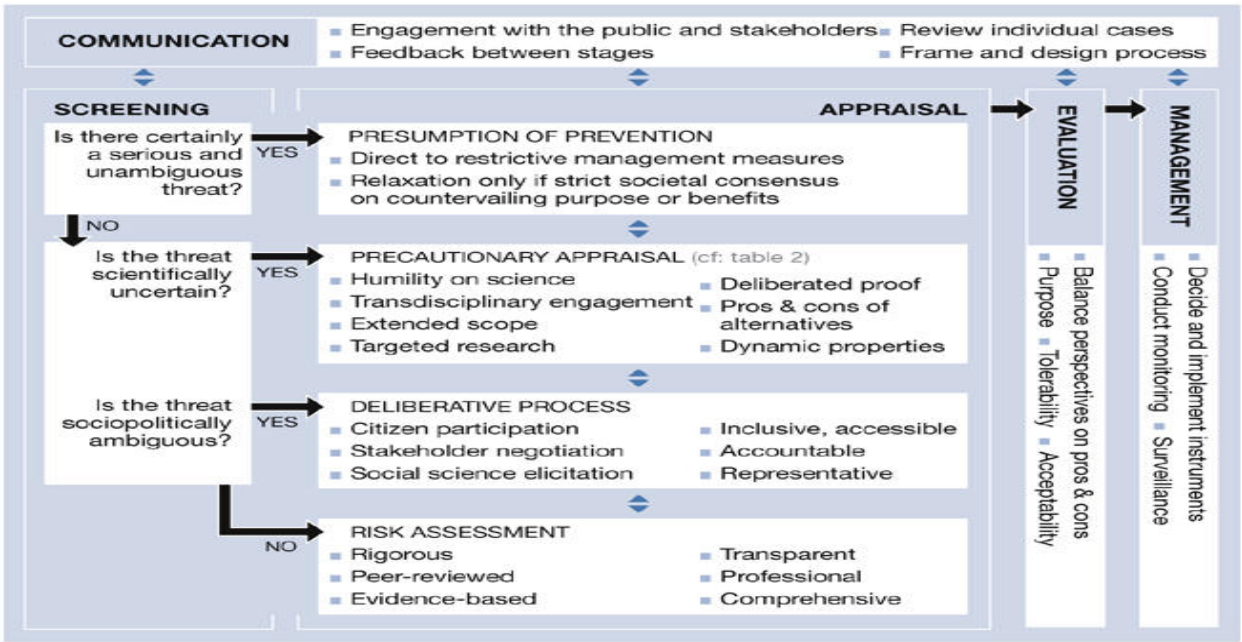

Fig. 6. Combining the risk assessment method with the precautionary principle (Stirling, 2007)

In this sense below would be presented the Apell for mining, which is guidelines created by the United Nations how to raise the awareness and prepare for emergencies on a local level.

APELL

Before discussing in detail the exact steps proposed by the Apell framework, first, there would be discussed why is the Apell framework beneficial and what are the companies already doing in that direction.

The benefits of the APELL framework are reviewed at the beginning of the report. In the first place, the actions recommended lead to a reduction of the probability of a disaster occurring and the eventual consequences. If a mining accident occurs, this has a huge physical, financial and reputational impact on the company in addition to the harm to the population, therefore the implementation of the guidelines is profitable for all the parties. Secondly, the framework puts emphasis on creating a strong relationship between the mine and the population, which is useful not only in the case of an emergency but in general. Finally, transparent and proactive conduct from the side of the company would stimulate the population to feel safe and secure and would allow on one hand not to hurt the image of the company as badly as if an accident occurs and on the other would allow for faster recovery. (UNEP, 2001, p.4.)

Many companies are already undertaking various actions in sense of risk preparedness, such as voluntary codes, risk management, communicating and consulting with the opinion of the population, studies about the social and environmental impact to name a few. Therefore, the companies already have most of the information needed. For instance, an emergency response plan is in multiple countries a prerequisite for a license for a facility to start operation which should be submitted during the environmental impact assessment. The certification ISO 14001 is a useful tool in that sense (ISO, 2015). However, usually, the companies are creating those plans with a focus on on-side only and more rarely an off-site emergency response is included as well. More often than not, their generation occurs without prior consultation of the communities located near-by. Nevertheless, in the last years, there is a shift towards more inclusion of the latter. A good example of an emergency response plan creation involving the communities in the process is the Australian Minerals Industry Code for Environmental

Management (Satchwell, 2003). In the same direction goes the Boliden's Environmental Manual (Boliden, cited in UNEP, 2001, p.9). (UNEP, 2001, p.8)

The mentioned before are all examples of the advances the companies are making in direction of disaster preparedness. Nevertheless, some more actions might be required to be taken. Initially, the company has to create an emergency response plan and training and to test it regularly. Moreover, the population should be included in it and the issues it finds important to be also taken into account. Further, the company has to establish good communication with the communities located close by as well as with state and federal authorities, emergency response agencies etc., which would enable quick and efficient reaction in case of emergency. (UNEP, 2001, p.10)

After the above-mentioned points have been clarified, would be proceeded to the overview of the exact steps to be taken as suggested by the APELL framework. They are presented in the Fig.7. below.

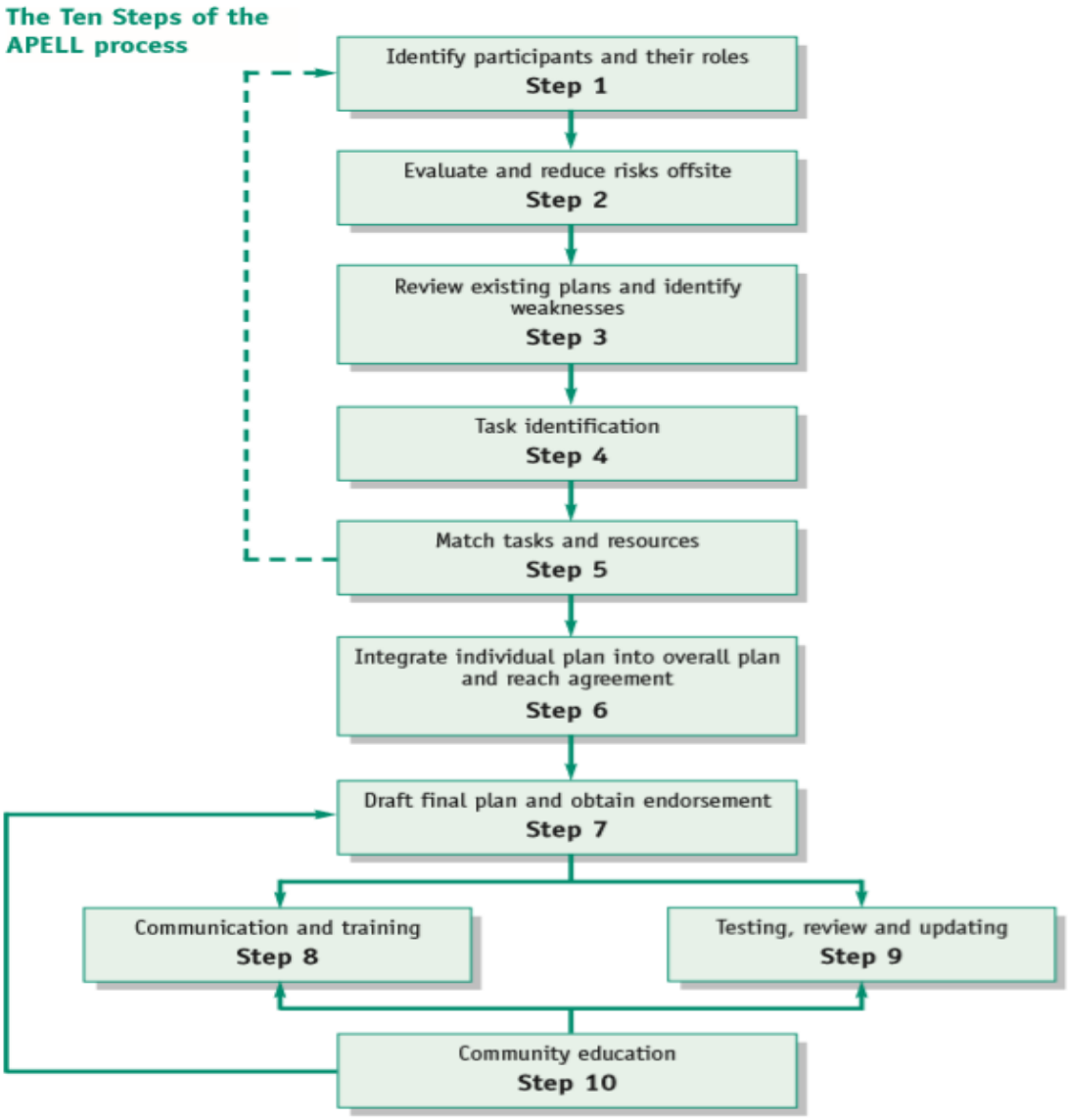

Fig. 7. The ten steps of the APELL process (UNEP, 2001, p.20)

The first step would be to create a list of all the people and entities which would take part in the emergency response, allocate resource to them and see in which area there is a lack of resources. For example, some mines are located in remote areas and have no or limited access to public emergency response services. In that case, the company has to be prepared and provide a similar service. (UNEP, 2001, p.21)

Fig.8. below shows a checklist of the possible participants involved in the emergency response.

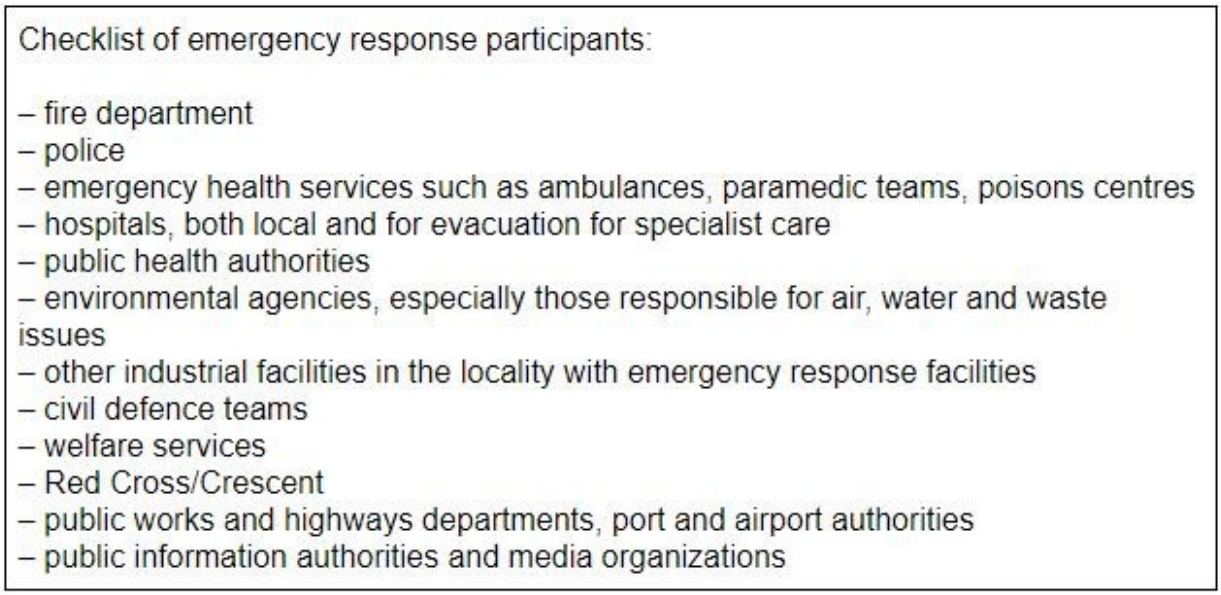

Fig. 8. Checklist of the emergency response participants (UNEP, 2001, p.21)

The second step is to list all the risks, which could lead to an emergency and the probability of their occurrence, as well as the eventual results and the possible aims to mitigate those risks and results. The company implementing APELL should review different accidents occurred before in the industry and in similar activities in other industries and include them as possible risks in their list. Further, the company should include natural disasters and seasonal treats which may occur. When it comes to the possible results, attention should be paid to the size of the area and the population, which would be eventually impacted, and how exactly; if the results would be long or short-term; if the environment would be deteriorated and if there could be secondary damages. When it comes to the propensity of an accident happening, 3 factors should be considered: what is the propensity of single events; of simultaneous events and what are the complications of a situation as result of the specific characteristics of the area, for example is the mine is situated on a major river which is responsible for the water supply of the area. After all of the steps above are being implemented, the time comes to list the means to reduce the different risks. Some of the risks could be eliminated easily or at a reasonable price and the others are kept further in the APELL process. It is very important to point out that the emergency planning process should be used additional and not instead of risk management and risk reduction. (UNEP, 2001, p.22)

In that sense, risk assessment is gaining popularity for use in the mining industry. Through software analysis could be conducted simulations of the effect on the dams as a result of static

or dynamic pressure. Example for the former is the volume of the tailings and for the second unexpected events such as earthquakes. This helps the decision-making process in relation to design, construction materials and to anticipate accidents. The stability of the dam could be increased by strengthening the foundation which would make the structure more resilient to shocks. (UNEP, 2001, p.24)

In the third step of the APELL process, the Co-ordinating Group should contact the different actors from the list in Step 1 and ask them to provide information about their proceedings related to the risks clarified in Step 2. Such emergency plans could be also accessed in UNEP and the Office for the Coordination of Humanitarian Affairs (OCHA) or requested from National Disaster agencies or coordinators. To make the process easier the Co-ordinating Group could create a check-list which is fulfilled by the relative agencies. (UNEP, 2001, p.24)

The items added to that list proposed by the APELL are the following (UNEP, 2001, p.25):

- There should be appliances to enable the communication with all the participants in the emergency, such as mobile phones or radio stations
- Established contacts with the media
- Keep an eye on the perils, such as contamination of the water and educate the participants on how to deal with them
- Provide the necessary gear to contain eventual discharges
- Have guidelines established for reporting
- Alarms installed
- The population trained for evacuation and the presence of emergency lodging in proximity
- Clear assignment of the responsibilities to all the participants
- Drinking water distribution prepared in case of need
- Know-how to deal with chemical contamination
- Quick examinations tool to analyze chemical contamination
- Strategies for restoring the initial state - as well as for the first moments of the event as for long-term

Later in step 4, the gaps between the resources and procedures available and the ones registered in Step 2 are determined and an importance rang is assigned to each of them. The coordination between the participants is essential in order to end up with an integrated

emergency response. Therefore, is crucial to have a defined command organization. (UNEP, 2001, p.25)

Further, in step 5 each of the deficiencies registered in Step 4 should be allocated to some of the participant's lists from step 1, as in the case is important to take into account the available resources, the expertise and the willingness to undertake the task of the latter. In the end, the competition of the task should be controlled. (UNEP, 2001, pp. 25-26)

In the next step 6, there is an integrative emergency plan designed according to the legislation, the outlined risks, and responsibilities as it should be ensured that there are no overlapping tasks. The plan should be tested through a role-play involving main actors so eventual discrepancies which are still not resolved would become known. Simple plans are more clear and understandable for all and are more likely to be used in case of emergency. It is very important to have a printed copy of the plant since during the accident there might be no access to computer, internet and the hard copy is quicker and more straightforward to use. There should be also elaborated a plan designed for an emergency clean-up after an accident. Of course, the actual impacts could be evaluated only after the disaster but already before that, different options in terms of logistics, benefits, and disadvantages could be analyzed which allows for quick and effective reaction in case of emergency. (UNEP, 2001, p.27)

In Step 7, a team is defined to write the actual plan and it should be presented to the population, government, and others. In some case, the plan would have to be officially endorsed. (UNEP, 2001, p.28)

In step 8, after being endorsed the plan should be presented to relevant participants of the emergency response and indicate who of them would need a training and what kind. Later the trainings are conducted as there might be a cross-training of different participants groups together with the aim to increase the knowledge and understanding of the tasks of one another. Another important point is to indicate a media spokesperson and train them as well. Emergency posters should be hung up in appropriate places and not the least field training ‘in monitoring, use of communications, traffic control, evacuation procedures, etc.’

In step 9, there is a team designated to design a simulation outline and another group which will not participate but will observe the simulation and will evaluate the actions according to the previously elaborated checklist. The first simulations should be conducted without the participation of the public in order to reveal eventual lacks still existing and only after including the population. After there should be an evaluation session where the simulations would be discussed. The plan should be tested regularly. (UNEP, 2001, p.29-30)

The report remarks at that point some issues which should be taken into account. The first is that each of the risk scenarios and the consequential outcomes defined should be tested. Second, the test should be conducted in different seasons, since the latter might play an important role in the case of an emergency. Another important point is that there might be (frequent) change in the management team and therefore it is important that the tests are conducted on a regular basis so the new managers get acquainted with the procedures and with their responsibilities. It is especially important to conduct the test when there are substantial changes in the some of the elements analyzed in the emergency plan, for instance, a new dam constructed nearby or other infrastructural changes as the construction of a new road or settlements; or even an almost occurred accident. (UNEP, 2001, p.30-31)

The last step of the APELL process is to communicate the emergency plan to the wide population and not only the engaged representatives. Transparent and close communication is recommendable during all the phases of the process but is especially crucial at that one. It is important that every single person who is prompt to be affected has awareness of the risks and how to act in case of emergency. For this aim, the people should be able to recognize an alarm when set and know what to do and when, where and how to evacuate, who they can contact and where to find information. Therefore, it is advisable to create a brochure which contains all that information, written in understandable language according to the level of literacy of the population and distributed through the most effective channels, e.g. post, door-to-door. Simulations could be conducted including everybody. Another important thing is to prepare the communication with the media, give them the necessary information, get them acquainted with the emergency plan and state how the media could be helpful. This is important since the role of the media in the time of a disaster is crucial and giving misinformation can provoke panic and hurden the crisis management. The media spokesman should be trained in advance and well prepared so he/she is most efficient under the stress situation of the burst of the disaster. Another suggestion in the APELL process is creating a website to be used in case of emergency, giving updated information about the disaster evolution, impacts. Competency in the emergency plan would be helpful also during meetings with the government representatives, investors, and external public. (UNEP, 2001, p.32)

The industry associations are usually not publically involved. Even though they should not do the job of the company, it is important that they also assist the public to understand the event, providing information. (UNEP, 2001, p.33)

In chapter 5 of the APELL Handbook are outlined different risks related to the mining industry in particular. Those are risk related to tailing dams-, waste dumps-, transport- or pipeline accidents; fires and explosions; subsidence; chemical spills or the ones related to already closed mines. In this work would be discussed only the first one.

Risks related to tailing dams

The tailing dams accidents have increased in the last decades. In that relation, the International Commission on Large Dams (ICOLD) and UNEP have jointly created a bulletin 121 called Tailing Dams: Risk of Dangerous Occurrences. Lessons learned from Practical experiences. The latter incorporates 221 cases of tailing dams accidents describing the background of the accidents; the triggers; what were the takeaways and which practices were conducted post-accident. (UNEP, 2001, p.34)

Dams, in general, are complex structures. A short overview would be presented based on information retrieved from the Bulletin 121 and Blog 2 Engenheiros. The tailing dams are constructed in order to contain tailings and have many similarities with embankments dams, whose aim is containing water. Similarities between the two are especially present in the cases when there should be water over the tailing in order to protect the air from contamination. Both, however, have many differences as well. Due to the nature of the contained material, the embankment dams are prestigious and involve in their design highly qualified engineers, while the tailing dams are responsible for the storage of waste, so they are aimed to be as economical as possible. In this sense, the later are a result from the work of skilled consulting engineers. Another difference is the length of construction time. The embankment dams are usually built wholly at once whereas the tailing dams are built during the whole lifecycle of the dam. Therefore, in the case of the tailing dams, many changes might occur meanwhile and the supervision could become deficient. There are differences in the construction materials as well. The water storage dams are built normally from concrete whereas the tailing dams made of sand and stones in order to hold the residuals and on the bottom there is not permeable clay keeping the aquatic layer underground safe from pollution (Blog 2 Engenheiros, 2017).

Moreover, in some of the countries, the tailing dams fall under the same legislation as the embankment dam, but this is not always the case. (ICOLD/UNEP, 2001, p.6)

There are three different ways to conduct dam crest raising. One is the upstream-raising when the crest of the dam is raised upstream the dam. Other two methods which use hydraulic backfill are the downstream and centerline raising. The upstream method, namely the one chosen by Samarco, is the oldest one, the most straightforward and cost-effective dam construction method. It proceeds like this: first, a starter dike is been built, after, the tailings are hydraulically collected in ponds (small formed lakes). The heavier, coarser particles of the slime deposit on the bottom of those ponds, making them stronger, while the finer particles pile on the walls of the starter dike and play the role of a filter for the excess water of the tailings. The solid portion would become a foundation for future raising dikes. When the maximum height projected is being reached the process is suspended. (Engels, 2006; ICOLD/UNEP, 2001 p.23; Salinas, 2016, p.10-11). Fig.9. is a visualization of the upstream raising method.

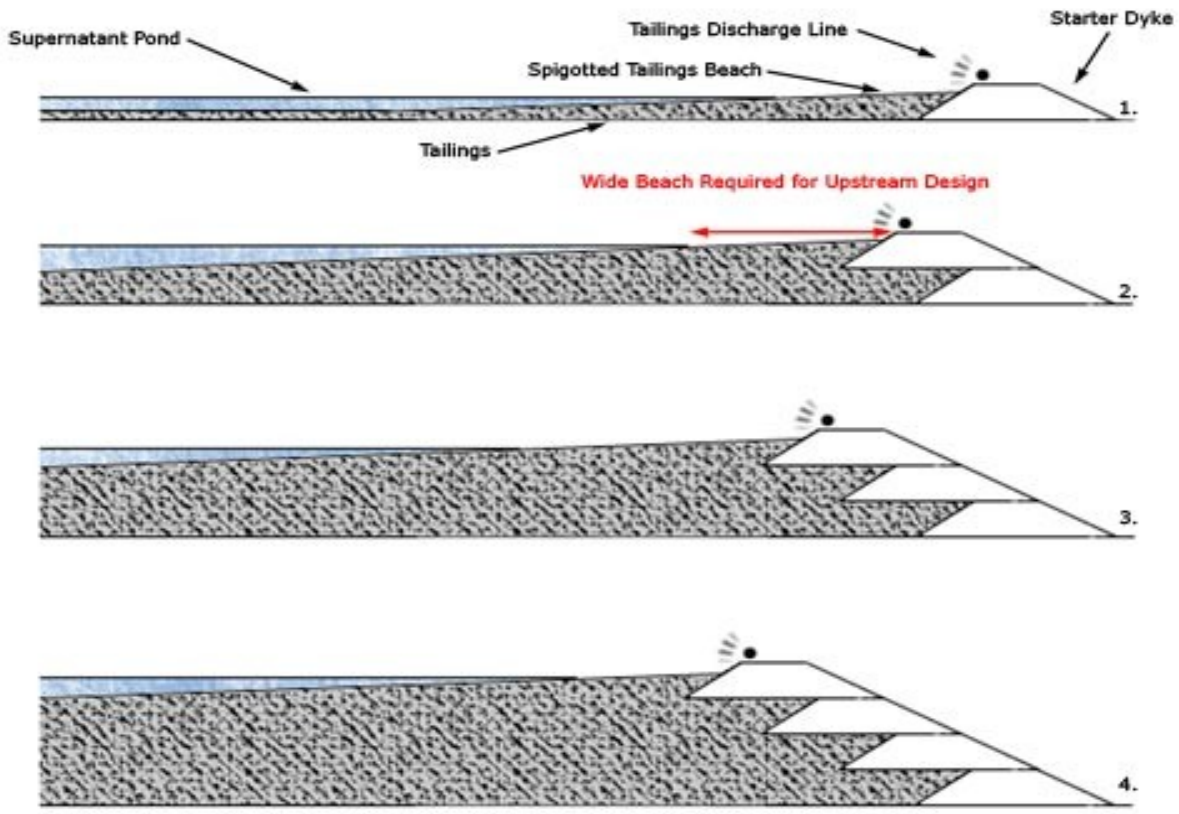

Fig. 9. **Upstream raising method - Engels, J. et al. (2004)**

The upstream rising method, however, has its disadvantages as well. It presents high liquefaction risk since the sandy portion might contain water instead of filtering it and becomes soft and saturated leading to disturbance of the embankments. It is also susceptible to earthquakes, therefore in Chile, which is highly seismic, the dry-stacking method is usually adopted. (Engels, 2006; Salinas, 2016, p.12) Shocking is the fact that half of all reported dam accidents which are a bit over 3500 have used the upstream raising design (Davies et al., cited in Engels, 2006).

The downstream rising method is used exactly due to the lower risk of liquefaction (ICOLD/UNEP, 2001, p.24). First again a starter dike is been built. After that, the rising is built downstream up to the maximum height of the dam project as the structure of the crest rising is much more stable since it is independent of the waste disposal. For material could be used the same as the one used for the construction of the starter dike and even a drainage system could be set up so there is a better control of the water containment. Due to the specific characteristics described above, this crest rising method is much more costly in comparison with the upstream one. (Engels, 2006; Salinas, 2016)

The centerline method is the middle ground between the upstream rising method and the downstream one since it provides more stability than the upstream one, however, the backfill material necessary for the construction is less than for the downstream method, respectively is cheaper (Benckert et al., cited in Engels, 2006). Moreover, it has a similarity in the tailing disposal system with the upstream method since the tailings are released from the crest of the starter dike, however, Constance is needed in the symmetry axis of the dam. This method is seen as a good option in seismically unstable areas, since due to its stability-cost relation. (Engels, 2006)

According to the experts, at least 1 large scale collapse per year occurs among the tailing dams per year worldwide, which is 10 times more than the statistic for the traditional dams which have a probability of rupture 1 out of 10 000, seen as safer (Davies et al., 2000). Only between 1981-2015, there were 24 dam breaches in Brazil, 7 only in the state of MG between 1986 -2015 (ANA, 2016, p. 21; Oliveira, 2015).

When it comes to the cause, tailings dams accident could be either natural, provoked by events such as an earthquake or heavy precipitation, or technical, as a result of calculation, construction or maintenance error. Usually, they occur due to one of these issues: problems in the drainage, liquefaction or accumulation of mud in the place where there should be sand residual, overflow, flooding, internal erosion or a mix of them. When an accident does occur, it has collocal impacts over the environment and the population since the waste coming as a by-product from the mining activity is often contaminated with chemicals and heavy metals. Those flow into the river and alter its natural chemical balance, leading to disturbing the consumption and irrigation water qualities. (Blog 2 Engenheiros, 2017)

ICOLD had published many Bulletins with guidelines for the safe design, building, and closing of tailing dams, which could be very useful for the people involved in such activities and if the former were to be followed, the number of the accident would drop. According to the bulletin 121, the reasons for the tailing dams deficiencies are usually 'lack of control of the water balance, lack of control of construction and a general lack of understanding of the features that control safe operations'.(ICOLD/UNEP, p.6)

Another example of guidelines existing on the topic is the one created by The Mining Association of Canada: 'A Guide to the Management of Tailing Facilities', which emphasizes the importance of the strict monitoring over all stages of the dams evolution including emergency plans for all of them. (ICOLD/UNEP, 2001, p.34).

Everybody is unanimous that the prevention is the best choice and its planning should be incorporated in all the processing, starting from where the dam should be built, evaluation of the risks and the stability, computer-based modelling reaching to survey of the populations in vicinity and down-stream, legislation, monitoring and surveillance (Blog 2 Engenheiros, 2017).

In Appendix 1 of APELL are outlined the wholesome list of items included in the emergency response plan (UNEP, 2001, pp 50-52) and in Appendix 2 guidelines for crisis communication from the European Chemical Industry Council's Book of Best Practice (UNEP, 2001, pp 53-55). These could be used as guidelines during the elaboration of the crisis emergency response.

Situational Background

Impacts and Impacted

3.1. Impacts and the impacted by the disaster

In this chapter would be described the impacts on the fauna, flora and the socioeconomic and health issues, which came in a result of the Fundao dam breach. Before that, however, would be discussed the trade-offs between the economic profit from the mining industry and the ecosystems preservation.

3.1.1. The trade-off between the economic profit from the mining industry and ecosystems preservation

There has always been a trade-off between the economic profit and the environment preservation. It is especially visible in the case of the mining sector. The mining activity provokes negative impacts on various aspects of the ecosystems. First of all, it turns landscapes with various different functions into monofunctional ones, whose only purpose is extraction (Neves, Barbieri *et al*., cited in Neves, Nunes, 2016, p. 25.). Second of all, especially strong is the impact of the industry over the freshwater as well as its use in the household or for irrigation (Carpenter et al., 2009; McIntyre et al., 2014, cited in Neves, Nunes, 2016, p. 25.). Those are endangered directly through the extensive use of the water in the mining processes. There is, however, an indirect impact as well in the form of pollution or even accidents as tailing dams failures (Li *et al*., 2011; Neves, Barbieri, *et al*., 2016, cited in Neves, Nunes, 2016, p. 25.). Regardless of the above-mentioned prejudice, the economic profit is more often than not still given priority. Part of the reason why this is happening is that the mining sector contributes to the budget of the state in terms of tax revenues. Moreover, the cost of losing ecosystems is being externalized from the costs, therefore, the cost-benefit analysis stays positive (MEA, 2005, cited in Neves, Nunes, 2016, p. 25.). Currently, efforts are made in the direction to include those values so they could be taken into account as well (TEEB, 2010, cited in Neves, Nunes, 2016, p. 25.).

However, during the calculations of the fines related to the disaster in Rio Doce, this internalization of the cost didn't take place. What happened, in that case, is that the highest fines possible with regards to the Brazilian law by the environmental agencies (IBAMA and

SEMAD) on state and federal level were demanded, namely US$349.2million (current dollar exchange rate of US$1 = R$3.90). Meanwhile, an extra-juridical agreement in relation to the restoration was signed between the company and its shareholders on one hand and the state of MG, ES, the Brazilian Union, on the other. Nevertheless, those values are just a fraction of the value of the ecosystem losses. Many compare the damages with the Deepwater Horizon case of BP in the Gulf of Mexico where the cost of the damages was estimated at US$54 billion. (Neves, Nunes, et al., 2016)

3.1.2. Impacts of the dam breach

The accident of the Fundao dam, Samarco, severely impacted the whole area of the Rio Doce Basin. There are numerous categories of damages: losses in terms of vegetation and biodiversity, socioeconomic and health impacts to name a few. Below, some of the impacts would be discussed. The information from this part is mainly retrieved by the paper written by Fernandes et al., (2016), based on information from various reports of different institutions.

3.1.2.1. Impacts on the flora and the habitats

The dam breach impacted severely the flora throughout the whole valley of Rio Doce. In order to measure the impact, a surface reflectance data in Landsat-8 images were used. The latter revealed area of 1469 hectares suffering an extensive loss of vegetation and 90% of the riparian habitats of the rivers Fundao, North Gualaxo and Carmelo. In that range were also located areas of permanent protection (APPs) and conservation units (UCs) such as the State Park Rio Doce, the State Park the Seven Halls, the Goytacazes National Forest and the Seven Halls Biodiversity Corridor in Aymoré (Wanderley et al., 2018). In addition, were reported the presence of very high levels of iron concentration in Rio Doce. Further, in the river could be seen various colored, from the tailings, spots reaching a width of up to 1 km in close proximity to the point of the accident. It should be pointed out that the Rio Doce is part of the Atlantic Forest, which is now also endangered by the pollution. Moreover, according to the Brazilian Ministry of Environment (MMA, cited in Fernandes et al., 2016, p.4.), the delta of the Rio Doce is very important for the marine species conservation due to its biodiversity which is also threatened due to the dam breach. (Fernandes et al., 2016, pp.2-4). What is more, 80km2 of the sea were affected by the mud (Camara dos Deputados, 2016,p.13).

3.1.2.2. Impacts on the aquatic fauna

On top of the impacts of the vegetation come the ones related to the aquatic fauna. Rio Doce was very rich in fish diversity. There were even many still unknown species. Moreover, 6 of the known ones were endangered with extinction. After the dam breach, the ichthyofauna was affected severely. Many fish populations died. In order to save as many species as possible, when the rumor about the accident spread, a project called Noah's Arc was organized by volunteers. (Escobar, 2015, cited in Fernandes et al., 2016, p.5.) Nevertheless, due to the limited time and resources, the project was implemented unsystematically so it can't be guaranteed that there were representatives from all the species populating the river. (Fernandes et al., 2016, p.4-5)

3.1.2.3. Socioeconomic impacts and human health risk

Having mentioned some of the impacts over the flora and fauna in the river, some of the socio-economic losses would be outlined as well. The dam breach is estimated to have caused more than 20 billion dollar material and environmental losses. In the coming years, 37 villages and cities would be impacted due to the reduced tax revenues and collection of royalties. After the accident, a situation of emergency was announced in thirty-five municipalities in Minas Gerais (Wanderley et al., 2018). Some of the damages are irreversible, such as human lives, lost biodiversity, landscape beauty, heritage site of Bento Rodrigues among others. About 1 million people in 41 municipalities were affected and at least 300 thousand suffered water supply interruption. (GFT; IBAMA and Neves et al. in Fernandes et al., 2016, p.6). The interruption occurred in 7 towns in MG and 2 in ES (Wanderley et al., 2018). Further, there were losses due to a temporarily interrupted operation of the hydroelectric plants. Moreover, many of the communities were sustaining themselves from the fishing activities which were prohibited for at least a year after the accident. There were as well many personal belongings, photos, and memories lost, which were related to the identity of the people. Finally, an impact could be felt as well on the cultural and spiritual values (Satterfield et al., cited in Fernandes et al., 2016, p.6). Very important is the impact the tragedy had on the relation the people had with the nature (Chan et al., cited in Fernandes et al., 2016, p.6) Further, the dam breach caused disruption of the tourism and leisure activities

in the area, which were an important source of income for the coastal communities . cited in (Fernandes et al., 2016, p.6). Moreover, were affected two archeological sites, 6 places which were culturally and historically important; others still uninspected; and part of the Estrada Real (Carmo, 2017, p.147).

The most severely impacted were the municipalities Bento Rodrigues, Paracatu de Baixo, Gesteira, Barra Longa and other 5 villages in the district of Camargo, in Mariana. There were at least 19 human deaths the majority being subcontracted workers of Samarco and inhabitants of the municipality Bento Rodrigues and more than 1200 people were left without a roof over their heads. (Wanderley et al., 2018) Not to forget, is the impact the disaster had on increasing the unemployment in the municipality of Mariana and the region and the destruction of various local businesses. (Camara dos Deputados, 2016,p.13).

Furthermore, the extreme impact had the accident over the fishing activities in the area. The latter was an important source of income and sustentation for a big part of the riverine communities, including Krenak indigenous community. It was as well very important for the development of the tourism activities in the region (Ecoplan-Lume, cited in Fernandes et al., 2016, p.4). What happened is that the breach of the Fundao dam occurred during a very important period for the fish-spawning. During that period, namely between 1st of November until 1st of March every year, the fishing activities were prohibited and the public ministry of labor was paying a monthly compensation to the fishermen in the value of minimal salary, 20% additional for each dependent member and a basic food corb. Due to the dam accident, it was decided that this financial compensation would be paid by the company Samarco, starting from 5. November when the accident occurred. However, this kind of monthly financial support is received by only 11, 000 people, although more than hundreds of thousands of people depend on fishing for a living (GFT, 2015). (Fernandes et al., 2016, p.7)

Another controversial topic is one of the heavy metals concentration in the water. The researches conducted show different results. The mining company Samarco and DNPM (National Department of Mineral Production) state that the tailings didn’t contain heavy metals and consequently don’t pose a danger of contaminating the water and depriving the human health. According to Samarco there was only increased metal concentration in the first days after the accident and then it went back to the historical values. Moreover, the company claims that the tailing contains mostly silicon-, iron- and aluminum oxides, therefore higher

concentration of metals in the water is not coming from the tailings of the dam, but rather from sediments deposited for a long time on the river bottom and now being resuspended by the mud wave. (Ibama, 2015, p.31)

The tests Samarco requested were conducted by 4 laboratories certified ISO 12025. The samples were taken in 57 points in MG and in 37 points ES and it was both the water and sediments analyzed. In relation to the chemicals' impacts in the organisms, indeed increased the concentration of zinc and arsenic was found, but they reject the relation with the dam breach since increased concentrations were found both in the mouth of the river, as well as to the south and to the north from that point. Moreover, the fish in the river was not impacted, differently from the one in the points commented above, so they claim that if the contamination was due to the dam breach, the former would have been impacted as well. Finally, in terms of the danger of the use of the water, the study rejected such a hypothesis. (Samarco, 2016a, pp. 1-7)

Nevertheless, the studies conducted independently by different academics, NGOs and state and federal institutions conclude the opposite. The results for a study conducted by the Minas Gerais State Water Agency (IGAM) on the water chemistry show high levels of arsenic, cadmium, copper, chromium, nickel, and mercury in water samples from the Doce River after the accident (IGAM, cited in Fernandes *et al.*, 2016, p.7.). The one with the participation of the Brazilian Navy found a higher concentration of selenium, lead, arsenic, and manganese in the water (MB, cited in Fernandes *et al.*, 2016, p.7.)

There were also other studies of different institutions which grouped up under the coordination of the Brazilian Institute of Environment and Natural Resources (Ibama) and the Chico Mendes Institute of Biodiversity (ICMBio), which indicated high concentration of heavy metals in the water and the aquatic fauna in the estuary of Rio Doce and in coral and algal reefs being part of the Preservation Areas in ES and Bahia (BA) (Bianchini, cited in Fernandes *et al.*, 2016, p.7.),and in the upper sediment layers (UFES, 2017, p.163) as well as having huge impact on the zooplankton (UFES, 2017, p. 241). In the water, for which chemical concentration guidelines are outlined in CONAMA resolution 357, released on March 2005, and in the shrimp and fish, regulated by ANVISA resolution 42, released in August 2013, the content of lead, cadmium, and arsenic was between 9 and 115 times over the norm. Those high concentrations of heavy metals might lead to considerable health risks of the population dependent of the water of the river for consumptions, agriculture, farming,

fishing, etc (Dellinger et al., cited in Fernandes *et al.*, 2016, p.7.). The former might end up in the human bodies by being inhaled, swallowed or touched (Behling et al., 2014; Passos et al., cited in Fernandes *et al.*, 2016, p.7.). According to Islam et al. (as cited in Fernandes *et al.*, 2016, p.7.), it might occur by consuming contaminated plants planted in contaminated soil (Puschenreiter et al., cited in Fernandes *et al.*, 2016, p.7.), consuming meat from animals who gazed in fields exposed to the contamination (Terán-Mita et al., cited in Fernandes *et al.*, 2016, p.7.) or consumption of fish and seafood inhabited contaminated water (Appleton et al., cited in Fernandes *et al.*, 2016, p.7.). Moreover, the impacts of contamination might persist since the currents are moving the sediments (EMBRAPA, cited in Fernandes *et al.*, 2016, p.7.), which would cause secondary contamination of the aquatic fauna. Its levels might reach unforeseeable heights overpassing the safety limits (Järup, cited in Fernandes *et al.*, 2016, p.7.). The most would be impacted the populations which rely on the local fish as a mean of sustainment and the ones which are prompt to health issues (Ackerman et al.; Adger; Bose-O'Reilly et al.;
Ohlander et al., cited in Fernandes *et al.*, 2016, p.7.).

Due to the ambiguity of the results, the people from the impacted population don't feel safe to use the water from the river and buy mineral water to drink and cock (Greenpeace, 2017, p. 24). Similarly to fishing, the increased concentration of heavy metals might have impacted the soil quality and fertility for an unpredicted period. (Wanderley et al., 2018)

In addition to all the short-term effects can be added the long-term effect of the changes in the riverbed of Rio Doce. As a consequence to the sediments decanted on the river bottom more floods could be expected in the coming years and especially in areas for which that might have been unusual before (Wanderley et al., 2018)

During the emergency response, great attention should be paid that the actions taken are not being counterproductive to the future wholesome recuperation (Speldewinde et al., cited in Fernandes *et al.*, 2016, p.7.) Moreover, some restoration projects conducted, later on, might also affect the sediments and increase the dangerous exposure (Rocio et al., cited in Fernandes *et al.*, 2016, p.7.).

Costs of the disaster for the company

After there have been discussed the losses caused by the disaster, the attention would be shifted to their monetary value. Since the disaster is still ongoing and the proceedings are not yet determined, it is very hard to say what was/is the cost of the disaster. However, here would be outlined some of the costs the company had to bear.

First of all, the operations of the company have been suspended ever since the disaster, making for huge losses for the company (Samarco, n.d.-a). On top of that, the Samarco has to pay the cleanup and recovery costs. There has been a TAC agreement, signed in March 2016, according to which the company agreed to pay BRL 20 billion in the course of 15 years. There is a separate proceeding filed by the Prosecutor's Office charging the company BRL 155 billion which was the estimation for the damages as a result of the Deep Water Horizon. Moreover, the Company had received a total of BRL 500 Million from the side of the environmental agencies. (Salinas, 2016, pp.39-43) Further, the shareholder BHP Billiton has suffered great losses due to a drop in their shares value after the accident.

If effective prevention measures had been taken, the disaster wouldn't have occurred or at least the losses would be limited.

Samarco

Samarco is a Brazilian mining company grounded in 1977 and is currently held as a joint venture between BHP Billiton do Brasil Ltda., a Brazilian subsidiary of the Anglo-Australian Group BHP Billiton and Vale S.A. each with 50% share. BHP Billiton is the on the leading position worldwide for diversified miner producing iron ore, diamonds, coal, petroleum, bauxite, copper, nickel, and uranium. Vale, on the other hand, is a leader in the production and export of iron ore and pellets. However, they have also a very strong production of other minerals such as copper concentrate, bauxite, alumina, aluminum, potassium, kaolin, manganese, ferroalloys, and nickel. (Samarco, n.d.-d)

In economic terms, Samarco is a very important player in the Brazilian economy scene and especially in terms of exports. In 2015 the value of the Samarco's exports was BRL 191 million representing 1% of the whole Brazilian exports, making the company the 12th largest exporter in the country. The company is especially important for the states where it is located,

MG and ES, contributing with BRL 50 million and BRL 32 million taxes respectively. (Samarco, n.d.-c)

The mining company is producing iron pellets, made of iron ore which has been subject to a beneficiation process. The pelletizing process is the one in which the material is shaped in small spheres with a diameter between 8-18 mm. Those are used as input in steel plants for the production of various steel products used in construction, transportation, electronic devices industry to name a few. (Samarco, n.d.-a) The product is exported to Africa and the Middle East (23,1%). Asia not including China (22,4%). Europe (21%), the Americas (17%) and China (16,5%) (Wanderley et al., 2016, p.31.). In 2015 the company produced 24.9 millions tons of iron ore, earning BRL 6.5 billion. (Samarco, n.d.-b)

The company has 3 thousand direct employees and 3,5 thousand indirect ones. (Samarco, 2014, p.12.) The headquarters of the company is in Belo Horizonte (MG) and has offices in Vitoria (ES) and abroad in Amsterdam (Holland) and Hong Kong (China.) (Samarco, 2014, p.13.) The company owns two mines, the mining complex Germano in Mariana and the Alegria mining complex in Ouro Preto; 3 proceeding plants in MG located in Mariana and Ouro Preto; tailing dams and sterile piles. In addition, in ES, in Anchieta, they own the Ubu complex where there are the 4 pelletizing plants and the port. 3 pipelines also in the possession of the company with length 400 km each, cross 25 municipalities in the two states, of MG and ES. The company owns as well the hydroelectric plant Muniz Freire (ES) and Antonio Diaz and participates in a consortium of the Nova Era plant (MG). (Samarco, 2014, p.15.)

In 2014 the mining company implemented the Fourth Pellet Plant Project (P4P) in which the company projected the construction of a third beneficiation plant in Germano. Third slurry pipeline and fourth pelletizing plant in Ubu. (Samarco, 2014, p.13.)

Samarco has an integrated system which allows it to have control over the whole process from the mining extraction to the export and allows for cost reduction. The mining process occurs as follows: initially the iron ore is extracted from the Germano mine then it is transported to the beneficiation plants in MG where the ore is processed and the undesired elements are taken out in order to increase the iron concentration of the ore. The ore extracted in the mines

of Samarco contain mostly quartz and hematite particles. The former is removed during the beneficiation since it is difficulting the steelmaking process later on. (Reis et al., 2006, p.161.)

During the beneficiation process the ores are crushed, grinded, and undergo processes of floating and desliming. Initially, the iron ore has 46% concentration of iron and at the end of the process, it is processed in the form of a concentrate/slurry with an iron concentration of 67% (Samarco. Production Process cited in Salinas, 2016, p.2.). This slurry contains about 30% water and is transported via the pipelines to Ubu in ES where are the pelletizing plants. The slurry is first filtered and then through the balling process, the pellets are formed and then are treated with heat to get harder. (Samarco, 2014, p.13). Fig.10. below visualizes the mining process.

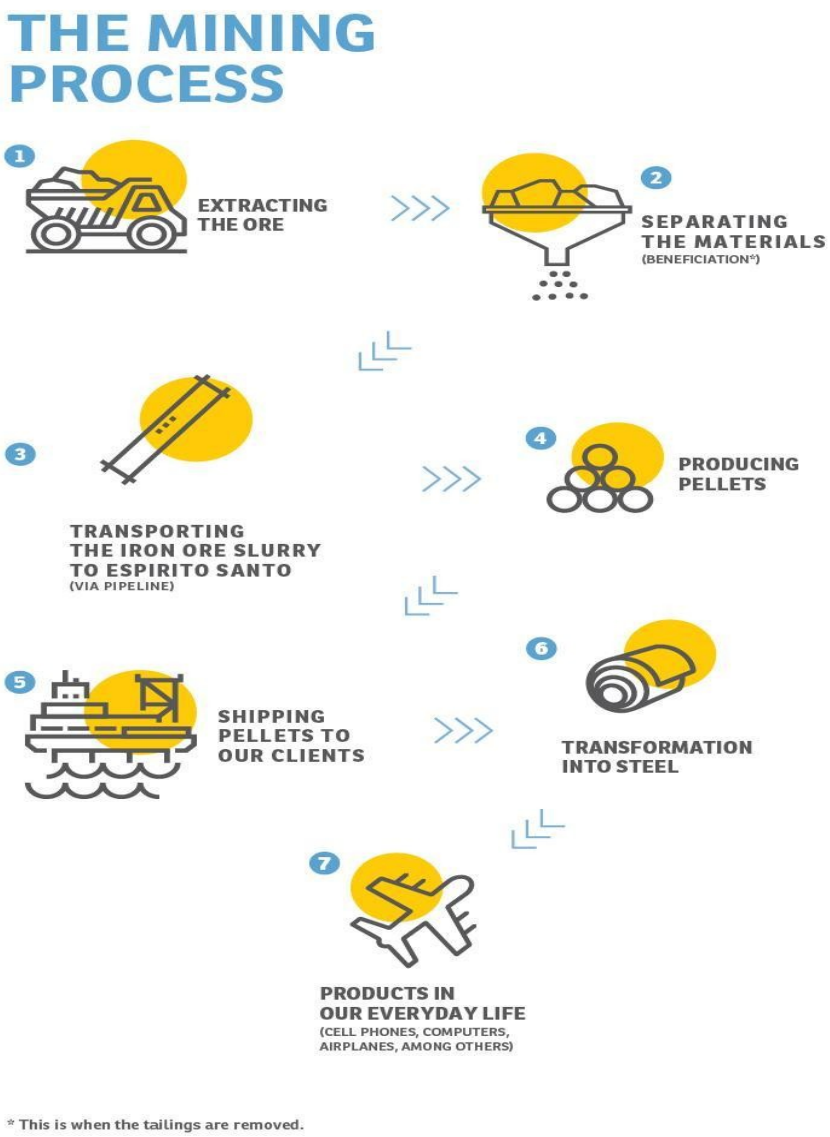

Fig. 10. The mining process of Samarco (Samarco, n.d.-a)

In terms of sustainability, before the dam breach occurred Samarco was often given as a good example. It was honored for its environmental engagement and was a role model in the CSR, being the first mining company to acquire ISO 14001 for environmental friendliness in all the production processes. According to a ranking of the Reputation Institute, Samarco scored 74,9 in a scale from 0 to 100 making the company a benchmark for the industry. (Almeida,2016)

The company as well has participated in the Global Pact of UN between 2002 - 2016 and signed several other sustainability-related Pacts such as Sustainable Development Goals (SDG) in 2015, as a continuation to the Millennium Development Goals from 2000; Business Contribution to Promoting a Green and Inclusive Economy, in 2012 during the Rio+20 conference; Open Letter to Brazil on Climate Change in 2009 and Business Pact for Integrity and against Corruption in 2006 (Samarco, 2016).

Samarco emergency action plans

Again in the sustainability report from 2014 Samarco confidently states its emergency preparedness and shares that in the same year emergency simulations in relation to the emergency reaction capacity of the company were conducted 6 times. (Samarco, 2014, p.21) It is also referring to the Emergency Action Plan (SAP) for dams of the company, which is legally proven and based on it, Samarco has invested 1,356 hours to train the staff directly or indirectly involved with the relevant activities. (Samarco, 2014, p.72)

Samarco's Risk management according to information from Samarco

The Risk Management of the company is based on the company's policy for Risk Management and the Manual of Corporate Risk Management (Samarco, 2014, p.21) as well as on the Enterprise Risk Management (ERM model); on the Committee of Sponsoring Organizations of the Treadway Commission (COSO); and guidelines of the stockholders Vale S.A. and BHP Billiton Brasil (Samarco, 2016). The process starts with pointing out the risks and classifying them in categories, evaluating their probability, searching for solutions to mitigate them and monitor the evolution of the process. Multidisciplinary seminars are held

during which the risk assessment involving most of the above-mentioned steps is conducted. (Samarco, 2016)

The risks were classified depending on their nature as being legal, market, health, safety or environmental related, and according to the time span of the impact over their business as strategic, operational, project, financial/compliance, and health and safety. The company is reviewing those risks annually in order to account for any changes happened inside, new projects, performance, or outside the company, eg. market trends, iron prices. (Samarco, 2014, p.21)

In the years 2011-2014 checklists were created by the company with regards to the Foreign Corrupt Practices Act (FCPA) and the UK Bribery Act. Documents about Communication and Socio-institutional Development; Port Operations; Geotechnics and Dams were created in 2014 and Health and Safety Guide and Waste Disposal adding to the Geotechnics and Dams Guide were planned for 2015. (Samarco, 2014, p.21)

In 2014, the company conducted 30 risk assessment seminars with the participation of 300 employees in total, in whose center were the strategic, operational, project categories. As a result, 23 material and 48 non-material risks were defined and 500 initiatives were planned in order to eliminate those risks. To each of the risks, there were allocated
action plans, whose success was evaluated monthly. (Samarco, 2014, p.21)

However, after the breach of Fundao dam, there were some changes in the Risk Management. The risk started to be divided into clusters: geotechnical works, business continuity plan, financial, legal and compliance. Moreover, the reviews became more frequent, namely on a quarterly basis and whenever something crucially happened. Further, in 2016 the number of seminars conducted was doubled, the number of employees involved almost tripled. (Samarco, 2016)

In relation to the dam risks, Failure Modes and Effects Analysis (FMEA) methodology was used related to the tailing disposal estimating the propensity of a dam accident and the eventual consequences on the dam structure and the health and safety of the people and the environment of such event (Samarco, 2014, p.72). There were also technical and independent audits conducted on regular basis. For example ITRB, Design Review, VIPs – Value

Improvement Practices – and IPA. Further, the FEL (Front-End Loading) methodology was used during the design and construction of the dams. The Tailings Disposal Plan (PDR); the compliance guide for dams; and the Emergency Action Plan for Mining Dams (PAEBM) were also used by the company. Finally, risk assessment related to the operations of the dam was conducted 5 times between 2011 and 2015, however after the accident 18 such took place only in 2016. (Samarco, 2016)

Samarco's Risk Management in Practice

The data discussed above is all retrieved from the official public communication of the company. Different, however, is the point of view of the human rights organizations Justica Global, which discussed in its report from 2016 the topic. The report cites a newspaper article according to which in 2009 the authorities set conditions to the company for the sake of granting an environmental license, namely to monitor the dam 24 hours and to put in place an alarm system to warn the population in case of emergency. Due to financial motives the company didn't comply with those requests. Nevertheless, the license was granted to the company. (Justica Global, 2016, p.9.) Another point the report discusses is that according to the Emergency Plan of Samarco there should have been simulations conducted including the communities located close to the dam, but in reality such inclusion was never done (there is a document signed by different entities of the civil society and social movements and sent to the National Council for Human Rights, on 16 November 2015). Further in the report is presented another responsibility of the company which it didn't undertake and namely to warn and remove the population in the vicinity of the dam (Werneck, 2015).

The report goes on with a critic that in the Emergency report of Samarco, as impacted by an eventual accident are stated only Bento Rodrigues, Ouro Preto and Mariana (Brandt, 2005, cited in PoEMAS, 2015, p.53) and excludes all the other communities and settlements, therefore is only a partial plan. (PoEMAS, 2015, p.53.)

The same report mentions about another inconsistency occurred during the process of revalidation of the Operational Permit of Samarco in 2013. Namely that the study warned about the possibility of a deficiency of the Fundao dam due to encounter with the sterile pile of the Fabrica Nova of Vale (Instituto Prístino, 2013, p.3-6). Regardless of that, the State Council of Environmental Policy (COPAM) of MG approved the license. Having in mind the

possibility of breach the company should have paid even much more attention to the creation of a wholesome emergency plan and prepared the population for the event. Among the recommendations of the report is stated that the authorities should not neglect their job and insist on it (Justica Global, 2016, p.11.).

Testimonies from the population show that the population was not aware of the possibility, nor were warned anyhow. (Justica Global, 2016, pp. 10-11). Disturbing is also the fact that the other two tailing dams of the Germano complex, Santarem and Germano are also endangered to failure (G1, 2015). That information was confirmed by the company only after the breach of Fundao, 12 days later to be precise. Moreover, the licenses of two of them are already expired since 2013 but they are nevertheless in usual operation according to information from the State Secretary of Environment and hydro resources, Sisema. However, according to the Brazilian legislation the licenses are automatically prolonged until a decision is been taken if the company applies on time for revalidation, which Samarco did. Therefore, the permits were in order for the time being. (Tinoco, 2015; Justica Global, 2016, p.11.).
Unfortunately, even on the legislative level, in general, there are examples for neglecting the environmental licensing processes in the benefit of economic interest. One such example is the project proposal for relaxing and integrating the environmental licensing process, PLS 654/2015 submitted to the Special Commission of National Development of the Senate. According to the latter, there would shorten the time for environmental analysis related to the licensing, eliminating the possibility of the population to participate in the decision-making process and reduction in the control and surveillance of complex infrastructural projects.
(Justica Global, 2016, p.12)

According to Wanderley et al., (2018) Samarco completely failed in the emergency response at the moment and right after the accident, since the company only took some measures due at ‘the request of the rescue teams, popular pressure, and judicial intercession’.

Empirical Part

As Schoenberger (1991) expressed it ‘Case studies do not allow for statistical validation or generalization. They can, however, shed light on highly complex situations and possibly provide the grounds for developing testable hypotheses’.

Research question

The question which is set in the center of the current work is:

Is insufficient investment in disaster prevention a disadvantage for the company itself?

The hypothesis is that insufficient investment in disaster prevention is indeed harmful to the company since an eventual accident causes many costs and hurts the image of the company.

Methodology

Due to the nature of the researched topic, a case study was chosen as the most appropriate method to be used. A qualitative analysis based on semi-structured expert interviews was conducted. Expert interviews are interviews conducted with experts in a sense that they have expertise about the topic because of scientific knowledge or due to personal experience (Flick, 2014, pp.227-232.). Precisely this type of interviews was chosen since it allows for a more straightforward analysis compared with the non-structured ones. On the other hand, valuable information might have been lost if fully structured interviews were used, which now could be acquired. Moreover, there might have been issues of primary importance to the participants that haven’t been considered for by the researcher and in this way, those had the chance to emerge in the conversation. The weaker rigidity than the fully structured interviews allowed the latter to shift direction and to cover the topics which actually matter. (Atteslander, 2010, pp.124-125.) The interviews were recorded, transcribed and analyzed. Since the interviews were conducted in Portuguese, later a summary was made in English. For the analysis was used the Content Analysis Method (Novy et al., 2008, pp. 10-30). It aimed to outline the important issues mentioned in each of the interviews. The latter were grouped in categories. Most of the interviews were conducted face-to-face but since it was not always possible having in mind that all the interviewed are situated in Brazil and the researcher in Vienna,

other channels were also used, in particular: email, WhatsApp and Skype. Those turned out to be very beneficial since it allowed for follow-up questions and clarifications and access to updated information. Having in mind that the case is still ongoing and there are many aspects changing constantly, that was crucial.

In order to acquire a wider understanding of the disaster, different kinds of parties were interviewed. Among them, there were people from the affected population, firefighters, civil defense and the federal emergency response team, who are always the first to come to the area of a disaster. There was an interview conducted with a representative of the MAB organization, which is fighting for the rights of people affected by dams. There was as well email communication with people from Renova Foundation, who also answered some of the questions. They were, however, focused on some unclarities which arose during the research. There was as well communication with the mining company Samarco, responsible for the disaster. From the company, however, didn't respond to the questions sent. Moreover, an interview with a lawyer was conducted in order to get understanding how is the Brazilian legislation functioning, what are the general proceedings, is there some specific disaster prevention foreseen by law, what are the sanctions etc. Further, an extensive interview was acquired from a person who had worked for the city council of Mariana but insisted to remain anonymous. Finally, interviews with people working in governmental agencies such as Ibama (Instituto Brasileiro do Meio Ambiente e Recursos Naturais, Brazilian Institute for Environment and Natural Resources) and DNPM (Departamento Nacional de Producao Mineral/National Department for MIning Production) were also held.

The interview questions could be found in Appendix B of the present work. The questions presented are the ones which were elaborated before the interviews. However, since the interviews were in semi-structured format, there were other questions which arose during the interview and were also asked meanwhile. The questions elaborated for Samarco, as mentioned earlier, were not answered, however, they are also included in the list of the interview questions. Hopefully, they are helpful to people conducting future research and having more luck to get in contact with the company or as well for researchers investigating the same or similar topic in different enterprises.

Even though all these interviews were important in order to understand different aspects of the disaster, not all of them could contribute to responding to the research question posed. Nevertheless, they are included here and the main issues mentioned are extracted.

The analysis included that all the repeated issues in the different interviews are outlined and in brackets is written by how many interviewed they were mentioned.

Results

In Appendix, C would be presented those repeated issues among the different interviewed and some interesting statements which were not repeated nevertheless reveal an interesting and enlightening, sometimes shocking, information about the case. Since the focus of the current work is the prevention, here would be copied all the comments of the people related to the emergency response (in a sense of evaluating what went wrong so it should be improved and what went well, so it should be kept that way) and the prevention. The issues which were repeated would be in bold and with a number in brackets, showing how many times they were repeated.

- **Prevention**
    - No effective enforcement of the preventive measures was accomplished.
    - Brazil there is a wide range of environmental norms, such as laws, regulations, ordinances, codes and other regulations, better and more complete than in many other countries, however, there is a lack of effectiveness in the application of these rules.
    - **needed effective surveillance and state control (2)**
    - If precaution is implemented effectively, there would be a considerable reduction of the amount and the impact of the accident and in the consequence of the environmental damages.
    - Prevention is very necessary
    - There is a preoccupation post-disaster in the preparation and simulation but not before that
    - Deficiencies in prevention, preparation
    - **The need for empowerment of the people (2)**

- The computer modeling to evaluate which communities should be included in the communication plan, only Bento included since no one expected such a great accident, nevertheless, the communication with the population in Bento was also absent.
- The word event that is incorporated in the TAC agreement is a creation of Samarco, who insisted on it, didn't even admit it was a technological disaster. However, the technical experts of the civil police of MG, federal police and the MPF proved that it was known by the company the clear change of dam breach, nevertheless it didn't take the precaution measures needed.
- When the population asked the company of the chance of dam breach, the response was that they don't have to worry about that and that the dam is secure.
- There were never open proposals to displace the village of Bento.
- Interviewed also want to know why more investment was not made in prevention.

- **Emergency response**
  - The worst case prepared for in the emergency plan in case of a dam rupture was that the tailings would reach maximum the other dam Santarem but the impact was way bigger.
  - **The communication (of Samarco) was full of flaws. (2)**
  - No post psychological assistance to the impacted
  - The state is not prepared to face events like that
  - there is a lack of communication, integration of the emergency groups.
  - There is a lack of effectivity, logistical support, salaries, resources in the public sector
  - **The MAB was the first ones to support. (3)**
  - The mayor Duarte Junior did implement very professionally the protocol of the national security
  - There were places in the impacted area which could be reached only by plane
  - The emergency response teams had a unified command for the first 40 days which functioned very well
  - **Learned about the disaster from a relative or neighbor. (3)**
  - **Mutual help among the inhabitants during the disaster. (3)**

- Military police informed the municipalities only until Paracatu, 50-60 km away from the accident, the further ones weren't informed
- During the emergency actions, that the civil defense did an excellent job. There was also the support of the forces of the state government which sent all their forces.
- a problem that so many donations arrived, which had to be organized and there was no more place to put them.
- MAB held reunions with the affected and providing them with psychological support
- Emergency issues that MAB was involved in:
  - the rights of people to bury the dead bodies
  - the right of the families to be lodged and to have resources to sustain themselves to have access to mineral water.
  - That the emergency actions were related to saving people, taking them out of the mud, bringing them to the shelter in the Arena of MG.
- The day after the accident a machine came to clean up the way, they were taken to the Arena in Mariana and the city hall already had organized everything; food, clothes, and mattresses from donations
- **The district attorney is very good and the population receives a lot of rights/achievements due to him, Guilherme Meneghin. (3)**

Summary of the results

Below are outlined the repeated by the interviewed issues in relation to prevention and emergency response.

- **Prevention**
  - **needed effective surveillance and state control (2)**
  - **The need for empowerment of the people (2)**
- **Emergency response**
  - **The communication (of Samarco) was full of flaws. (2)**
  - **The MAB was the first ones to support. (3)**
  - **Learned about the disaster from a relative or neighbor. (3)**
  - **Mutual help among the inhabitants during the disaster. (3)**
  - **The district attorney is very good and the population receives a lot of rights/achievements due to him, Guilherme Meneghin. (3)**

Recommendations

How can the issues mentioned by the interviewed be used to improve the disaster risk management of the company: Lessons to be Learned.

1. Don't build dams so close to a community and if so occurs displacement should be negotiated as an option and the community should be aware of the risks of staying.
2. Invest in prevention sufficiently.
3. Apply the APELL framework.
4. Create an emergency plan including even the low-possibility events.
5. Chose an emergency management team.
6. Effective enforcement of the preventive measures should be ensured by the company.
7. Strict surveillance and governance should be ensured from the side of the authorities.
8. Regular and transparent communication between the company and the population, but as well across the different states and municipalities which could be impacted.
9. The company and state should ensure transparent and truthful information
10. An alarm warning system should be installed in order to allow for the quick notice of an emergency situation.
11. Eventually, build an emergency wall between the dam and the municipality.
12. Install devices to measure the volume of the tailings in the dam and the pressure of the water on the soil.
13. Regular clean-ups of the sediments of the river bed, allowing for quicker outflow.
14. Conduct simulations with the population.
15. Sufficient resources should be prepared for the case of an emergency.
16. Build resilience of the population.
17. Be prepared for the worst case.
18. Plan for communication and integration of the emergency groups should be elaborated and practiced in advance
19. Include in the process the community, even indigenous ones.
20. Create an emergency fund from the beginning of the potentially impactful activity.

For the case of emergency

1. psychological assistance to the impacted should be provided
2. a unified command of emergency response teams should be ensured

Challenges during the elaboration of the current work

Below would be stated some of the challenges encountered while doing the current research:

- Logistic problems (time period, flights, accommodation, financing, equipment in sense of recording device, and vaccines) related to a field research in Brazil.

- Difficulties in preparing in advance the research, in a sense of getting in contact with the right experts, such who could enrich the research with their expertise and being willing to participate.

- The organization, which is dealing with the event, Renova Foundation is overloaded with work. They have pressing deadlines and have to be in different places at different times so it's very hard to schedule an interview with them. Moreover, the institution is highly bureaucratic so there are long processes to get one interview. In their office, a person can get in only with a scheduled interview, so it is also very restrictive.

- It is also hard to have access to the one who is responsible for the field in the interest of this work.

- The victims are already fed up with the researchers going there and asking the same questions without doing anything to fix the situation.

- Difficulties arise as well from the nature of the event, namely the damages are not fixed and final, but they are still occurring. Respectively, there is new information coming up, which might be contradictory, for instance, agreements being signed but not ratified, or being ratified but criticized and then later changed.

- Many newspaper articles are written on the case but few scientific ones.

Conclusion

The discourse around the disaster is very problematic due to its nature. There are so many different interest groups involved, therefore could be differentiated so many different layers. Some of the issues, which pose difficulties in resolving the case, are conflicts between the

environmental protection and economic profit, policies, legislation, bureaucracy to name a few.

In order to avoid events like the one in Mariana, more attention should be paid to the prevention. On the one hand, the companies should invest in effective prevention and well-planned emergency response plans and on the other hand, the authorities should play their role of surveillance so the proposed measures are actually enforced.

The current work started with a detailed description of the Fundao dam breach and its immediate consequences. Further was discussed the theoretical background, including disaster risk management; prevention; overview of the APELL framework and risks related to the tailing dams. Later on, the situational background of the event was laid, starting with the post-disaster impacts; the cost for Samarco; Samarco company's description and its Risk Management and Emergency Preparation and Response. After that, was described the empirical part conducted, including qualitative interviews. Based on the interviews a content analysis method was used to define which are the issues, which were repeated by multiple interviewed and with the help of those issues the recommendations of improving the prevention of a company were elaborated.

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Appendix A: Abstract

Being good or bad take turns all the time, especially when it comes to money. A big mining company provides the majority of the residents with work and providing them with their source of living for years. Suddenly, a disaster occurs. Due to stingy investment all goes wrong. The tailing dam turns out to be incorrectly enlarged, cheaper namely, for the time being, much more expensive afterward. The contaminated with chemicals dirty water breaks free and get out of control washing away everything of its way. The impact is enormous: completely destroyed villages, 19 lives taken away, pollution on an extreme level, biodiversity endangered, not to count the cultural and social connections destroyed. This is what happened on 5. November 2015 with Rio Doce, in the state of Minas Gerais in Brazil. The guilty - the mining giant Samarco who provoked the disaster, regarded as the 5. worst natural disaster in the history. Could it be different? What could the company have done about it in advance? What if it had effectively invested in prevention measures? These are some of the questions which would be discussed in the current work, examined with the help of experts interviews. Based on the outcomes of those interviews some recommendations were elaborated.

Abstract in German

Die Rolle gut oder schlecht zu sein, dreht sich ständig, besonders wenn es um Geld geht. Ein großes Bergbauunternehmen versorgt die Mehrheit der Bewohner mit ihrer Arbeit und versorgt sie seit Jahren mit ihrer Lebensgrundlage. Plötzlich und eine Katastrophe tritt auf. Wegen geiziger Investitionen geht alles schief. Der Rückhaltebecken erweist sich als falsch vergrößert, billiger, vorläufig, aber viel teurer danach. Das mit Chemikalien verunreinigte Schmutzwasser bricht frei und gerät außer Kontrolle, indem es alles wegspült. Die Auswirkungen sind enorm: Völlig zerstörte Dörfer, 19 umgekommene Menschenleben, extreme Umweltverschmutzung, Biodiversität gefährdet, die zerstörten kulturellen und sozialen Verbindungen und so weiter. So geschah es am 5. November 2015 mit Rio Doce im Bundesstaat Minas Gerais in Brasilien. Der Schuldige - der Minengigant Samarco, der die Katastrophe provoziert hat, gilt als die 5. schlimmste Naturkatastrophe in der Geschichte. Könnte es anders sein? Was könnte das Unternehmen im Voraus getan haben? Was, wenn es effektiv in vorbeugende Maßnahmen investiert? Dies sind einige der Fragen, die in der aktuellen Arbeit diskutiert und mit Hilfe von Experteninterviews untersucht werden. Basierend auf den Ergebnissen dieser Interviews wurden einige Empfehlungen ausgearbeitet.

Appendix B: The interview questions

For people of Samarco

- What kind of measures and procedures did the disaster prevention implement in the company include?
- How were these measures implemented?
- How was the implementation monitored?
- How was the implementation controlled?
- What was the investment in disaster prevention? (precaution)
- Is there a dedicated team to risk management? / disaster prevention?
- How important was disaster prevention to the company?
- Does the company have previous experience in disasters? (Does it have the knowledge how is it done in other companies/ other cases)? (there were some accidents occurred in the dam and there was an emergency action plan implemented and the fault was removed (Foudao investigation report).. technical wise, but did they plan what to do in case of a big event like the one that occurred)
- Is disaster management implemented in the company's strategic planning?
- Are there special technical EDV (computer programs) systems used for risk management?

To the victims

- How was the day of the event?
- What are the consequences over your life?
- What changed after the disaster?
- How do you finance yourself? How is it working?
- Do you receive compensation from Samarco and is it enough?
- What is your contact with the company now? Are they taking care of your needs/ your requests?
- What has been done as compensation/restoration so far?

To the lawyer

- Which jurisdiction is that case – MG/ES/federal/international (due to the impact over the ocean) / is TTAC enough and do they have the right to sign such a treaty?
- What is the general proceeding of such cases?

- Are there specific disaster prevention measures/precaution foreseen by law? (especially having in mind the industry - mining, which is dangerous per se)
- Are environmental, social, cultural costs included?
- Who and how controls the implementation of disaster prevention measures?
- What are the instruments the government is using to control/monitor/punish if needed the implementation of disaster management? In the stage of prevention as well as the restoration?
- What are the foreseen by law sanction? (liability)? Does it depend on the level of precaution the company has taken? (it is judged by strict liability or negligence principle)
- How can a stricter control be ensured?
- How can compliance be ensured from the side of the government?

To public representatives

- What is the usual proceeding in disaster prevention? Which are the measures? (precaution)
- How are these measures implemented?
- How is the implementation monitored?/ controlled/ sanctioned? (liability)

Appendix C: Repeated issues among the interviews and some interesting comments:

- **Corruption** - especially related to the point that in Brazil the mining companies are allowed to make donations for the electoral campaigns of the politicians so they act in their favor once they are in power. Therefore, there is a strong economic power of the mining companies over the politicians. (3)
- **Political games** - the donations revealed in Mariana for the victims were actually used in electoral campaigns for mayor and councilors. (2)
- The **mining industry** should invest more in education and health care (2)
- Related to **Samarco**:
    - the company is probably not extracting only iron ore, but gold and other minerals (2);
    - BHP Billiton is thinking to sell its shares of Samarco to Vale (2)
- In relation to the **disaster**:
    - No one expected such a colossal event (everybody said);
    - Many people suspect that it was not an accident, but done on purpose and that Samarco had desires for the area where Bento Rodrigues is, already for a long time (2), (since it would be the best place for a new tailing dam of the company. Such was needed it due to an increase in the production, respectively in the amount of the tailings.);
    - However, the company expected that the impact would reach only as far as Bento Rodrigues the most, which was not the case (2)
- Emergency response:
    - The communication system was full of flaws (2);
    - No post psychological assistance to the impacted (2);
    - The MAB was the first ones to support. (3);
    - Learned about the disaster from a relative or neighbor. (3);
    - Mutual help among the inhabitants during the disaster. (3);
    - The district attorney is very good and the population receives a lot of rights/achievements due to him, Guilherme Meneghin. (3)
- **Impacts of the tragedy:**
    - Unemployment, many people are leaving the city since the jobs left there are very badly paid. (4);
    - Depression (3);

- Separation in the society: the population of Mariana thinks that it was the fault of the people from Bento that the company is not operating and that Mariana suffered lack of services because of the people from Bento. (4)
- illnesses provoked by the contamination in the result of the dam breach - skin irritation, respiratory problems, marks on the skin, hair loss, headache, yellow fever outbreak started after the disaster. Heavy metal contamination identified, which could lead to infertility or cancer.(5);
- contamination of the water with heavy metals - proved after blood tests of the population of Barra longa, 11 out of 11 tested are contaminated. Whoever can afford it buy mineral water, but most of the people can't and keep on drinking the tap water regardless of the risks. (2);
- indigenous communities not included for participation in councils (2);
- Lost friends (3);
- The deaths might be more than officially declared. (2);
- The agriculturists - only know how to plant, seeing the earth infertile, is like losing someone from their family, lose their identity. (3);
- Lost of memories, photos in the mud - lost of identity. (2);
- The negative impact of the disaster over the fishing activities. When the fishing was prohibited, the fishermen who already had fish couldn't sell it, or if they tried they were imprisoned. (3);
- the life in the city is much more expensive. Before they were producing everything, now they have to buy. Electricity is also more expensive. (3);
- lost contact with their friends, with whom they used to go to sit outside in the evenings, now everybody is dispersed through the city. (2);
- the company planted plant over the mud in Bento to hide the scene of the crime. (3);
- The residuals keep on going down the river, the disaster hasn't stopped yet. (2)

- **Compensations:**
  - Ridiculous compensation values - BLR 4,37 for a lemon tree. (2)

  - the company gained the power to decide who is a victim and who not, to register them according to their own understanding. In that process, many of the affected were excluded as no eligible for financial support.(3)

- **Renova**
    - Renova employees get very high salaries BRL 29 000 and don't pay taxes. At the same time while the company doesn't have money to compensate the affected population (3)
    - Renova that has 4000 employees but that nobody knows who they are, they are not people from Mariana who were left without jobs after the disaster or previous Samarco workers (2)
    - Renova promised a lot, but not doing anything - 2 years and 6 months and nothing is done, they just go to reunions all the time, which don't bring anything (4)
- **Legal**
    - Juridical proceeding and negotiation would take a long time, bureaucracy (3)
    - environmental fines in Brazil are never paid. The companies appeal them and get liberated (3)
- **Prevention**
    - needed effective surveillance and state control (2)
    - The need for empowerment of the people (2)

Below are plotted some of the comments of the interviews which were not repeated nevertheless reveal an interesting and enlightening, sometimes shocking, information about the case:

- "In the area, most of the people didn't have jobs in the company."
- "But already before, Samarco knew exactly who had what, because every month, there were making a reunion and were entering in the houses to see how many TVs everybody had etc. since there were some explosions during the mining activities they were going in the houses to check if they were impacted."
- "They were about to build in 2017 a dam in Miranginhas which is neighboring Bento. When the company was having this project they were doing the research about the belongings of the people and was asking them, if one day they are to leave the village, where would they go."
- "The devastating impact it would have been if the disaster happened during the night."
- "The worst case prepared for in the emergency plan in case of a dam rupture was that the tailings would reach at maximum the other dam Santarem and the impact was way bigger."

- “There was a misinformation in the media about the local of the accident, always named to be the city of Mariana.”
- “The tailings were not toxic but what could have occurred is that the mud wave has moved old toxic sediments decanted on the bottom of the river channel.”
- “The company has a policy for extremely low indemnization and has the strategy to individualize the repair.”
- “There are strategies to separate the people from the side of the company in order to restrict collective cases. Prohibited the access of the people of MAB to the affected population, while opportunist lawyers had access when the people were moved to the hotels.”
- “There is no doubt that the resettlement of Bento didn’t occur yet because the company wants to avoid collective resettlement.”
- “The TAC agreement of 20 billion - done without any technical studies and exact ideas how much are the damages; putting a roof on the amount of the money charged from the company, the whole agreement was to a great extent beneficial to the company, rather than the ones of the people.”
- “After the agreement was denounced as invalid, the company still kept on implementing the clauses which were beneficial to them but not the ones which related to the benefits of the affected.”
- “The affected people had no idea what is the value the company estimated for their houses and possessions.”
- “No effective enforcement of the preventive measures was accomplished.”
- “In Brazil, there is a wide range of environmental norms, such as laws, regulations, ordinances, codes and other regulations, better and more complete than in many other countries, however, there is a lack of effectiveness in the application of these rules.”