Think out of the bottle

Imagine...
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Purification with ‘Caerula’

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Introduction
Water which makes you sick when you drink it, brown water you have to bath in, dead animals floating on the water. Do you want this for your fellow human beings? We have the chance to actually do something.

We are three students from secondary school OSG Sevenwolden Fedde Schurer in Heerenveen. We were introduced to Imagine by our biology teacher. We thought this was a great opportunity to make a change, so we decided to join the contest. Of all subjects, we thought the subject “magnetic fluids” was the most interesting one. We have chosen for this project because it would be a challenge for us to come up with something good. We had to come up with our own ideas.

Purified water is still scarce in the world, while the demand for water by people is increasing. Although two thirds of the earth's surface consists water, many people in the world still have no access to clean drinking water. This is because only three percent of the water on earth is sweet, but also because the water is often seriously polluted by various substances out of nature or by the agency of men.
Especially factories play a major role in the pollution of water by dumping their wastewater in the nearby rivers. The goal of our project is to make the water in the Yamuna blue again, instead of brown. That’s why we called it ‘Caerula’ which means blue colour in Latin.

In this report we will explain the technique and what our business plan is. The first part of the report is the technique to purify the water is a separation with colloids. This is how we clean the water of heavy metals.
The second part of the report contains our business plan, including costs, customers and more.

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Our country

India

The Republic of India, or Bharat Garayja, is the home of one of the world's 'great' civilizations. India is not a country but a continent, in fact a sub-continent pointing as a peninsula into the Indian Ocean. India, divided by the Northern tropic, extends from the green Himalaya Mountains and the Ganga plain in the north, to the tropical forests in the south. It's runner up on the list of countries by population with its 1,210,193,422 people. The total area of India is 3,287,263 km^2, 9,56 % is water. The first language is English which makes the country very attractive for entrepreneurs, but there are so many other languages.

Climate

The climate of India resolves into six major climatic subtypes, because it is so big. This makes it hard to give you a general overview of the climate in India. In the West and North-West there is a desert-climate and a steppe climate. The highest parts of the Himalaya have a mountain climate. In the South and East is a savanna climate and at the West Coast in the South, on the Laccadive, the Andaman and Nicobar islands, is a Monsoon Climate, which is typical for India. In India there are four seasons:
Winter: from December to April, with temperatures around 10-15 degrees.
The summer or pre-monsoon: from April to June with temperatures around 32-40 degrees.
A monsoon or rainy season: lasting from June to September. It is a humid southwest summer monsoon.
The post-monsoon: from October to December.

Culture

Religion is an integral part of the total Indian tradition. India was the birthplace of two of the world's great religions, Hinduism and Buddhism. It also gave birth to Sikhism and Jainism. Zoroastrians and Jews have also become part of Indian life. So you can say there's a religious diversity. India's art, religions and languages differ from place to place within the country. India is known for its Caste System. This system is a social structure in which classes are determined by heredity. This caste system was the expression of the feeling that people from completely different standing and position in society also several precepts, rules, prohibitions, moral concepts and obligations were to have. The system divides the people into four main castes. These are compared to the head, arms, torso and legs. From top to bottom: the Brahmins, Kshatriyas, Vaishyas and Shudras. These castes are divided in more than 3000 subcastes and each of them has its own status, traditions, rules and prohibitions. Nowadays, the boundaries stagger between the castes by the necessities of independence, the requirements of industry and transport, by the reservation of certain government jobs solely for outcasts and by the rebellion of women against the old ties of their inferior position. Women are having a hard time in the society. Girls are seen as a burden on the family, they leave the family when married and an adequate dowry must be supplied. One of the consequences is that their education is neglected. Women, most of the time teens, may find themselves married of to a man she has never met. Their status is little better than that of a slave. The middle-class woman has a much better life, but there's still pressure.

India is a country of festivals and events. The most famous one of them is Diwali, also called 'The festival of lights'. This is a Hindu Festival of five days. They celebrate the victory of light over darkness, symbolic of good winning from evil.

Economy

India is one of the 'world's fastest growing economies'. This is a list based on the GDP of a country. The GDP is the total monetary value of all final goods produced in a country and services during a specified period. The Indian economy is worth US$1.848 trillion and it's the tenth-largest economy by market exchange rates and is, at US$4.457 trillion, the third-largest by purchasing power parity. The PPP is a way to compare the purchasing power of two

countries. The economy is divided in a few sectors: agriculture, Industry, ICT, Mining & Oil and Fishing & Forestry.
The Industry is the most important one for this project. The Industry in India contains telecommunication Industry, automotive Industry, Indian IT Industry and bio- and Pharmaceutical Industry. In India there are four Heavy Industries: Bharat Heavy Electricals Limited, Larsen & Toubro Limited, BGR Energy Systems and AIA Engineering. We're going to take a closer look at the Bharat Heavy Electricals Limited.
Bharat Heavy Electricals Limited is a company based in New Delhi. It's a power plant equipment manufacturer and operates as an engineering and manufacturing company. The production of these power plants produces heavy metals. The factory dumps the heavy metals in the Yamuna River.

Politics
India is world's most populous democracy. It's a parliamentary constitutional republic with a multi-party system. It has six national parties and more than 40 regional parties.
The government comprises three branches: executive, legislative and judicial. The President of India is the head of the state and is elected indirectly by a national electoral college for a five-year term. At this time the president of India is Pranab Mukherjee. The legislature of India is the bicarmel parliament. It consists an upper house called the Rajya Sabha (Council of States) and a lower house called the Lok Sabha (house of people).
India is divided into 28 states, of which ten with a population of more than fifty million people, 6 union territories and 1 national metropolitan territory called New Delhi. New Delhi is also the city capital of India.

Infrastructure
The infrastructure is getting better and better, they still have the old British railway system from the time of the British Domination. They have a few ports but navigable rivers are scarce. The traffic in India in major cities is very busy and uncontrolled. But they are concerned with the construction of major highways and better roads.

Why India?
The goal of our project is to make sure that the rivers in India will be less polluted by heavy metals. We want to do this by approaching the source, the fabrics. So for this project, we have been looking for a place where there are many heavy metals in the water, which causes problems. And secondly, we have been looking for a place where the factories the main cause of the pollution are. By looking at these two points, we came to the idea of the country India, especially New Delhi with the Yamuna (River). Yamuna is the sub-basin of the Ganga river system. The pollution of the Yamuna is a growing problem since 1990, by the rise of industry. In the 1990 the water of the Yamuna was 'clear blue' compared to the water of the Ganga, but now it's one of the most polluted rivers in the world. The recent economic boom is a good thing, but there has not been regulation on waste handling. The capital dumps 58% of its waste in the river, including the heavy metals from the factories. Adding to this hefty problem is the fact that the economic boom increased the population even further. In fact, the toxins have polluted the ground water and soil. It has entered our food chain through the vegetables which are growing on the banks and continues to affect the people living on the riverbanks. We've also had look at the business climate, because it's necessary for our project that we are not limited by costly and complex procedures. Technical and highly developed countries aren't attractive for entrepreneurs, a low-wage country is more attractive. We also have looked at the political, cultural and social situation. The business climate isn't that good.[1]

However, with our project we don't have a lot to do with the government and complex procedures. We sell our products directly to the factories, which makes it a lot easier. The

[1] Appendix A: Article

social and cultural situation is also good, there's a huge diversity in religions, but that doesn't make any difference, because the situation between those religions is okay. There aren't any conflicts. The social situation isn't that good because of the Caste System, but that doesn't affect our relation with the fabrics either. So all in all, India is a very good country for our project.

Which problems do we solve?
We want to ensure that the river is not going to be more polluted, by approaching the source of the problem. The water from the river can be used in abstracted or in non-abstractive form.

Irrigation is an important use of the river water. 92 % of the water of the river is used for that. The river water is abstracted at different locations for a lot of things, including drinking water supply. It's also used for domestic water supplies, hydropower development, fisheries, bathing and washing.

The heavy metals are bad for the health of people, animals and plants. We want to make sure that the drinking water will be cleaner and plats will be growing faster. We also want to make sure that the health of people and animals improves.

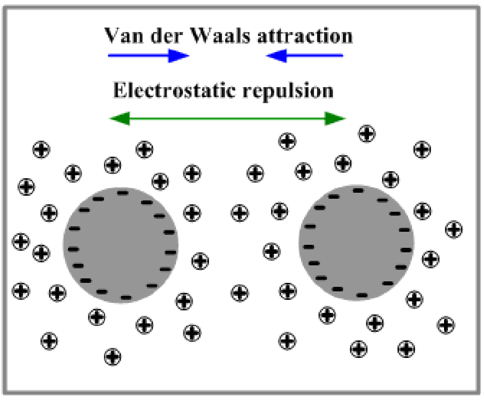
Who will take advantage?
The people who drink and wash themselves in the river. Also, the amount of fish in the river will rise, which is good for the market. The animals that drink water and wash themselves are also making use of the water. Our project is also good for the biodiversity. Because the Yamuna is a tributary of the Ganga, the water in the Ganga will improve, which has implications for (almost) the entire country. We are focusing on the people who can't afford clean water because it's too expensive. Also, the factories can make some money because the heavy metals from the water that we have obtained, can be resold, allowing them to make money.

Who do we want to involve in our project?
In this project we want to involve the factories. We want to involve the government as little as possible. This will cause less costs and import duties, so we can execute our project cheaper and faster. This makes it more attractive for the factories. The employees of the factory will be indirectly involved in the project, they work for the factory but we don't contact a lot with them personally. The factories are also the ones who will execute the idea. In the factory, in this case the Bharat Heavy Electricals Limited, we place the purifying system.

Theory of the colloids

The "Caerula" ensures that the waste water of factories in India will be purified of heavy metals using magnetic fluids. However, what makes a fluid magnetic?

A ferrofluid is a fluid with magnetic features, but it is not iron in a liquid phase because when iron has been melted it loses its magnetism. A ferrofluid is a liquid that contains small particles which are magnetisable when it contacts with the magnetic field of a permanent magnet. Such a fluid is also called a dispersion. The small particles in the ferrofluid are colloidal nanoparticles, in this case maghemite (Fe_2O_3-coloids).



Colloids are larger than atoms but small enough to be affected by the Brownian motion. The Brownian motion is the random moving of particles suspended in a liquid or a gas where the particles collide with each other. The colloids have a size between 1nm (10^{-9} m) and 1μm (10^{-9} m).

The colloidal nanoparticles have a magnetic moment, which means that one side of the colloid is negatively charged and the other side is thus positively charged. This phenomenon works just the same by atoms as by colloids. Iron atoms have electrons around them and so do oxygen atoms. There is a difference in electronegativity between the atoms. Oxygen pulls harder on the electrons than iron so the oxygen-side of the molecule turns out to be a little negative and the iron-side a little positive. All of the magnetic moments of the colloids in a dispersion are pointing in a random direction.

In the water there are H^+-ions and on the surfaces of the colloids are OH^--ions who all have a negative electric charge. This phenomenon takes place because the water separates ($H_2O \rightarrow OH^- + H^+$) and the OH^--ions bind to the colloids. Now, because of the OH^--ions, the colloids repel each other preventing aggregation. In a liquid the colloids are homogeneously distributed by the Brownian motion. The dispersion is stable.
However, when a colloidal particle is brought to a short distance to another particle, they can be bonded to each other by the van der Waals force (a force between every colloid). This short distance can be achieved by adding ammonia. When ammonia is added, the following reaction takes place:
$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$
Now there are so many positive ions in the solution, so the repulsion between the colloidal particles will become smaller. If the attracting van der Waals forces prevail over the repulsive electrostatic ones, the particles will aggregate and the ferrofluid will be destabilized. [2]

After that, oleic acid, a hydrophobic substance, needs to be added. Every colloid is coated with a layer of oleic acid and the particles are in the oil phase. The now hydrophobic colloids don't want to be around the liquid water anymore, but want to be with other hydrophobic colloids. All the colloids form a whole.
The colloidal particles coated with oleic acid need to be dissolved in cyclohexane to make the dispersion stable again.

The Caerula will purify water of heavy metals like lead, copper and zinc.[3] These metals are ions in water, which means that they are soluble in water and cannot be filtered with a membrane. All metal-ions are positively charged.
When the magnetic fluid is added to the polluted water, the positive charged ions can be attracted to the negative charged OH^--ions on the colloids and thus they can make a connection. [4]

Once the connection is made, the ferrofluid, bound to the heavy metals, can be magnetized by a permanent magnet and all of the magnetic moments of the colloids are oriented to one direction.

Now the ferrofluid can be attracted to the permanent magnet because of the electrostatic forces. Then magnetic separation can take place. The supernatant, the purified water, will be removed.[5]

[2] Appendix B: Theory of the Colloids
[3] Appendix C: Heavy Metals
[4] Appendix B: Theory of the Colloids
[5] Appendix B: Theory of the Colloids

Experiment

Introduction:
In this experiment we are going to invest which ferrofluid works best to clean polluted water from heavy metals: magnetite or maghemite. We will use the heavy metal copper because copper has an obvious colour in the presence of ammonia (NH_3) in water, namely the colour bright-blue. After adding the ferrofluids maghemite and magnetite in different beakers, the copper-ions will bound to the colloids and the bright-blue colour will disappear the more copper-ions have been bound to the colloids.

Hypothesis:
Magnetite will work best, because it contains more particles than maghemite so there will be more OH^--ions bound to the surface of magnetite.

Requirements:
- 3 beakers of 100 millilitres
- two permanent magnets
- A solution of copper(II)sulphate and ammoniac in water
- Maghemite-dispersion
- Magnetite-dispersion

Our experiment comprises 6 steps:
1. Number the three beakers from 1 to 3.
2. Add 50 millilitres of the solution of copper(II)sulphate and ammoniac in water to all of the beakers.
3. Add to beaker-1 3.7 gram of maghemite
4. Add to beaker-2 3.7 gram of magnetite. (Beaker 3 is comparative material)
5. Wait a for about five minutes and after that bring all of the colloidal particles together by holding a permanent magnet at beaker-1 and beaker-2.
6. Compare the three beakers with regard to the colour of the solutions.

Conclusion:
We compared the three beakers with each other. The beaker-1 had the lightest colour blue than the beaker-2. Because the colour of the water in beaker-1 was the lightest blue, maghemite works best to purify water of heavy metals like copper. This means that more copper-ions have bound to the maghemite ferrofluid than to the magnetite ferrofluid. So our hypothesis is wrong.

The purification system

The tank

The first part in the system is the tank[6] with the colloids. The water containing heavy metals will flow from the tube in the tank. In there the heavy metals will form a binding with the colloids. When most of the colloids have been bound to the heavy metals, the pipe from the tank into the funnel will be opened.

The grids

The second part in the system is the grid[7]. In the funnel there are in total four magnetic "combs" [8]. Two of the "combs" on top of each other, will form a grid. Because there are four

[6] Appendix D: Purification System
[7] Appendix D: Purification System
[8] Appendix D: Purification System

"combs" there will be two grids. The reason we use two grids is that we wanted to have an optimum water purification system.

<u>The funnel</u>

The third part in the system is the funnel[9]. When the pipe from the tank opens, the water with the heavy metal and colloid binding will go through the grids. Because the grids are magnetic, the colloids with the heavy metals will be attracted to the grids and left behind on the grids. The water, now separated from the heavy metals and the colloids, will go through the gaps in the grids.

Separating heavy metal-ions from colloids

Now the heavy metal-ions are separated from the water. The next step is to separate the heavy metals from the colloids so the colloids can be reused. For this we use a semi-permeable membrane and the osmotic pressure. A semi-permeable membrane is a membrane that will allow certain ions through it. In our case the membrane will only let the heavy metal-ions go through it.

On one side of the membrane there is a high osmotic pressure[10]. On this side are the colloids bound with the heavy metal-ions. On the other side there is a low osmotic pressure[11]. What happens is that the heavy metal-ions will go to the side where there's a low osmotic pressure to make the osmotic pressure even. The colloids will be left on the other side because the membrane only lets the heavy metal-ions through[12].

On the side where the heavy metal-ions are, we add a NaOH solution. The heavy metal-ions will react with the OH^-'s from the NaOH solution and form a precipitation. This we can sell to buyers.

Business plan

Our goal

- ***Recycle***
  The heavy metals we separate from the water can be recycled. The metals can be used for other purposes.
- ***Cleaner river***
  The river where the factory dumps their waste water will be cleaner, because the factory won't dump water polluted with heavy metals anymore.
- ***Creating work***
  The system needs to be operated by people. This will create more workplaces.
- ***Making profit***
  The heavy metals gained from the separation, can be sold for money. The money can be used for example reparations, paying the employees, buying the materials needed for the project.

Realisation

To realise this project we need to:

- ***Purify*** the polluted water.
- ***Recycle*** the heavy metals.

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9 Appendix D: Purification System
10 Appendix E: Separating Colloids and Heavy Metal-ions
11 Appendix E: Separating Colloids and Heavy Metal-ions
12 Appendix E: Separating Colloids and Heavy Metal-ions

- ***Separate*** the heavy metals from the water and separating the heavy metals from the colloids.
- ***Communicate*** with everybody we work with. The factory that will use our system, the transportation company, our financers, the supplier of the needed materials, the people who use the river water, the employees and our own team.
- ***Educate*** the people who will operate the system.
- **Sell** the heavy metals and the purified water to make profit.

Key partners
The people who contribute to our project are the factory Bharat Heavy Electricals Limited and a transport company.
The factory Bharat Heavy Electricals Limited is the factory that will carry out our project. The factory also includes the employees. The factory has the job to manufacture the installation and needs to make sure that the materials they need for the separation of the colloids are ordered every month.
The best way to transport the materials is by shipping, because it is the cheapest way. There are several companies which ship goods from Rotterdam Port to New Delhi. To transport the materials to the factory we will have to rent a lorry and a driver for once a month.

Key resources
To realise this project we need:

- ***Labour***
  We need employees to operate the system. These employees are the inhabitants of India.
- ***Knowledge***
  We need to know where our system is needed and the people need know how it's going to be used and why they need it.
- ***Finances***
  We need to buy materials for the system, pay the transport costs of transporting the materials, we need to pay the employees and we need to pay for the education of the employees on how to use the system.

Customers
Our customer is the factory, and via the factory we will sell the purified water and the heavy metals. We have chosen for the marketing strategy diversification: a market where the customer segments are independent of and different from each other.

Revenue Streams

<u>In the beginning</u>
If we want to set up our plan, we need to get money first. Our plan is to raise some money by crowdfunding. Crowdfunding works like this: an entrepreneur wants to start a project but does not have the seed money he needs. To get this amount, he launches his project on internet and mentions the money he needs. The idea behind crowdfunding is that the little investments of individual companies together finance the whole project. Imagine is well known under scientists and has a good reputation. It is a plausible to get financial support for our type of project. We also want to raise money by sponsors. We were thinking about the Blue Water Foundation. This is a foundation which also has a plan to clean the Yamuna river and to create a better ecosystem in New Delhi, just like us. So we taught we could cooperate with them. With the money we will raise by crowdfunding and sponsors we will buy a part of materials we need to build the installation. This will be as much as possible, but this depends on the money we will raise.

The other part of the seed money will be paid by the factory itself, because it's an investment in the future for them. The factory will pay the wades and the transport costs. They will also pay for the materials we need for the purification process.

After a while
If we want some factories to buy our installation, we need to make sure there is a way they can make some money. This will do because they can sell the heavy metals or reuse those so they won't need to buy them new.
We want to make sure the factories can sell the heavy metals in the following form:
- Copper hydroxide ($Cu(OH)_2$): €38.50 per 250 gram.

When the water is purified from the heavy metals and the copper sulphate we want to sell it.
- 50 cents per litre:
  the "Caerula" purifies 5000 litres a day, which means we can sell a maximum of €2,500.- a day and €912,500.- a year. However, that is not realistic, because we are settled in the capital of the third-world country India. In New Delhi there are other possibilities to get clean drinking water so it would be more realistic if we could sell half of maximum amount (2500 litres a day, €.456,250.- a year).

Costs against Planet
We will need CO_2 for our project because the "Caerula" needs energy. So there will be air pollution. Also because of the transport of the materials we need during the process, the air will be polluted by CO_2. This will contribute to the global warming.
Depletion of natural resources is also a negative effect. We will use plenty of Iron oxides and natriumhydroxide (NaOH).

Profits against people
If we want the employees to understand the machine and to know what they need to do to make the machine work, we need to educate them. This is a profit against those people because they learn new things. People who drink water from and wash themselves in the Yamuna will take advantage of our project.

Profits against planet
The river will contain less heavy metals so it will be less harmful for those people and other organisms who live in and near the river. The biodiversity will be contained.

Cost Structure
Of course our project will cost some money. Here is a list of costs we will make.

Materials to make the machine
Bharat Heavy Electricals Limited dumps 5000 litres wastewater a day.
the "Caerula" will purify 1000 dm^3/litres water a time. To make sure we'll reach our goal that the waste water will be purified for above 90%, we need to make 100 litres ferrofluid. However, when the colloids and the heavy metal-ions are being separated, the process will still be running. That is why we will need 5 times 100 litres of the ferrofluid. While we were at the Colloid Masterclass we've also made 8 millilitres of the ferrofluid maghemite. If we want to make 500 litres of the ferrofluid (which is 62,500 times more than 8 millilitres), this is what we will need from each material:
- Iron(II) chloride tetrahydrate ($FeCl_2 \cdot 4H_2O$): 3.19 gr → 199.4 kg
  1 kg = €101.50, so 199.4 kg = €20,239.10
- Iron(III) chloride hexahydrate ($FeCl_3 \cdot 6H_2O$): 8.65 gr → 540.6 kg
- 3 kg = €294.50, so 540.6 kg = €53,071.40
- Ammonia (25%) (NH_3): 25 mL → 1,562.5 L
  10 L = €981.-, so 1,562.5 L = €153,281.30
- Nitric Acid (2M) (HNO_3): 240 mL → 15,000 L
  5 L = €19.20, so 15,000 L = €57.600.-

- Iron(III) nitrate nonahydrate ($Fe(NO_3)_3 \cdot 9H_2O$): 8,48 gr → 530 kg
  250 kg = €135.50, so 530 kg = €281.30
- Oleic Acid ($CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$): 7 mL → 437.5 L
  10L= €380.67, so 437.5 L = € 16,654.30
- Ethanol (CH_3CH_2OH): 36 mL → 2,250 L
  3 L = €313.-, so 2,250 L = €234,750.-
- Cyclohexane (C_6H_{12}): 0,5 mL → 31.25 L
  8 L = €389.50, so 31.25 L = €1,521.50

The total costs for the materials to make the ferrofluid will be €538,920.40

Materials for the separation

Every month we will need NaOH for the separation of the colloids and the heavy metals. The amount is unknown, because we don't how much heavy metals the factory will produce.
NaOH: 3 kg: €197,50→ per 250 gram: €16,46

Channels

First we need to transport the materials we will use to make the installation.
Second by we need to transport the materials we need every month for the installation.
We also need transport for the purified water, but this is once a week and it will be in the same city so the costs won't be high.
We also need to transport the copper hydroxides, but the costs aren't constant because we want to sell these in whole India and China. So it depends on how much we will sell and to which places.

Key resources

After the machine has been installed, the factory needs three technical employees to keep the installation running. The minimum wage of people in India is around € 4.27 (= Rs 308) a day. This won't be enough for them and their families to provide their primary needs. We want to give them a decent wage so that is why we won't pay them the minimum wage. They will get € 6.- (= Rs 432.90) a day, which means € 2,190 (= Rs 157,785.85) a year. Because we will need three technical employees, the costs of a year will be € 6,570.
Furthermore, a process engineer is essential. He will have the final responsibility of the process. He is responsible for the sale of the heavy metals, and for the technical employees to do their job well. Because of this, his salary will be around € 7.- (= Rs 505.34) a day, which means € 2,555.- (= Rs 184,476.53) a year.

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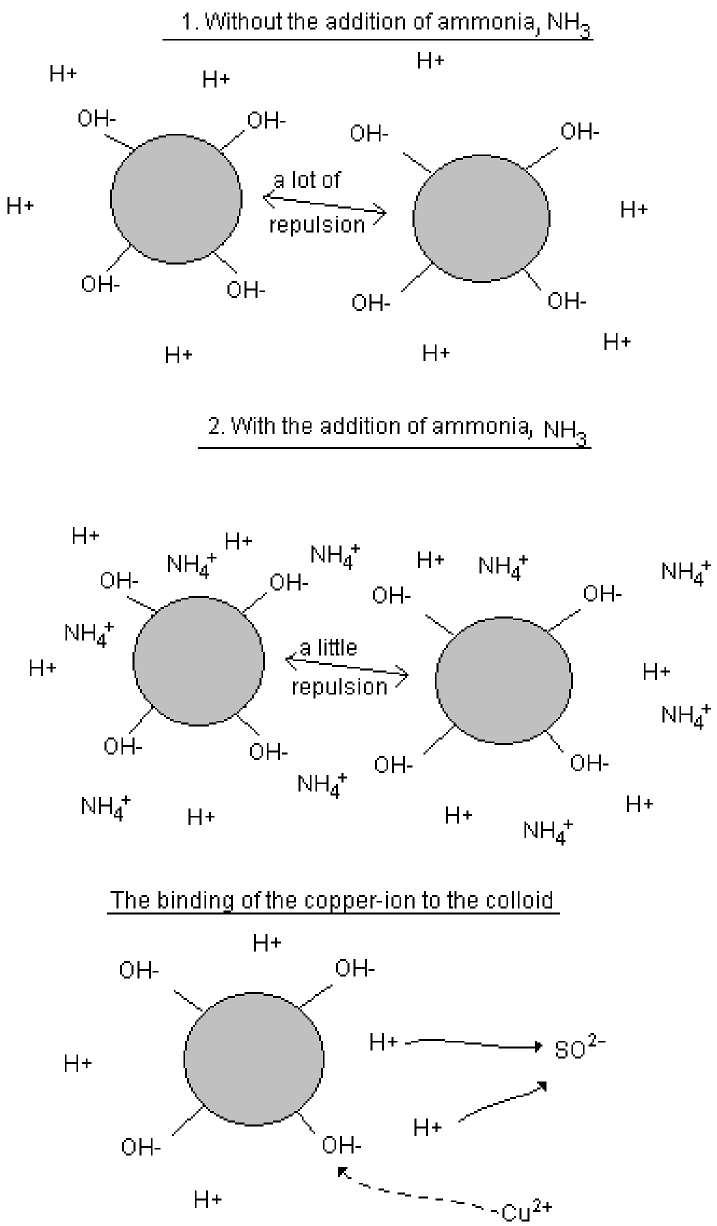
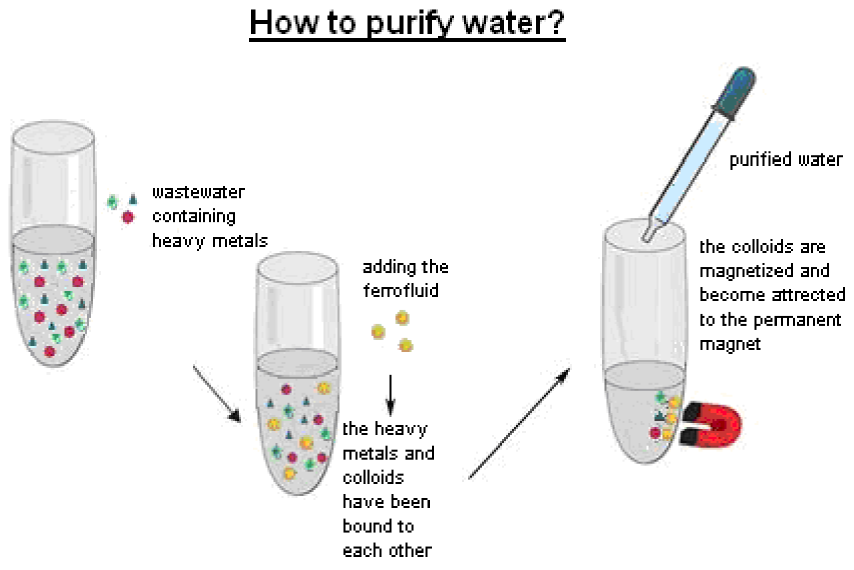
Appendix

Appendix A: Article

"Conducting business in India can be onerous. The situation is complicated by a lack of bankruptcy information, which frustrates credit risk assessment. Setting up a business and dealing with licenses are also problematic, as is corruption, the poor enforcement of intellectual property rights and the slow legal system (which delays dispute resolution). Firms dealing with India also complain of a largely inefficient banking system, with frequent delays in receiving funds overseas. In terms of India's relative competitiveness and ease of doing business there have been limited, incremental improvements over the past few years. These have been recognized by organizations such as the World Economic Forum and World Bank, but the challenges remain significant. The Indian economy ranked 56th (out of 142) in the World Economic Forum's Global Competitiveness Report 2011-2012."
http://www.agentschapnl.nl/onderwerp/india-wetgevingsoverzicht

Appendix B: Theory of the colloids





Appendix C: Heavy metals

Heavy metals are harmful to people's health and the existence of plants, animals and other organisms. Here is a list of the effects that can be cause by heavy metals which are most common in the Yamuna.

Lead:

Lead is a highly toxic metal and it affects almost every organ and system in the human body, especially the nervous system. Lead exposure can cause weakness in the fingers, wrists, or ankles and also causes small increases in blood pressure. Exposure to high lead concentrations can seriously damage the brain and kidneys of adults and children and can eventually cause death. The ingestion of lead is usually caused by the intake of food or water contaminated with lead, but it can also happen after accidental ingestion of lead contaminating soil, dust, or lead-based paint.

Copper:

Copper can be vital to all the living thing on earth (humans, plants, animals, microorganisms) because it causes health problems and environmental degradation.

Copper is as a trace element essential for human health, so the absorption of copper is necessary. Although humans can handle large amounts of copper, too much copper can still cause serious health problems. Long-term exposure to copper can cause irritation of the mouth, nose and eyes and it can also cause headaches, stomach aches, dizziness, diarrhea and vomiting. Chronic effects of copper exposure can cause damage to the liver and kidneys.There also are scientific articles which indicate a link between prolonged expose to copper and a decrease of intelligence of young adults.

When copper ends up in the soil it strongly attaches to organic materials and minerals and because of that it does not transport very far after the release and it rarely enters groundwater. In surface water copper can accomplish great distances, either bound to sludge particles or as free ions. Copper does not break off in the environment and because of that it can heap up in plants and animals. There is not much plant diversity near copper including waste water dumping factories. Only a limited number of plants has a chance of survival on copper-rich soils.

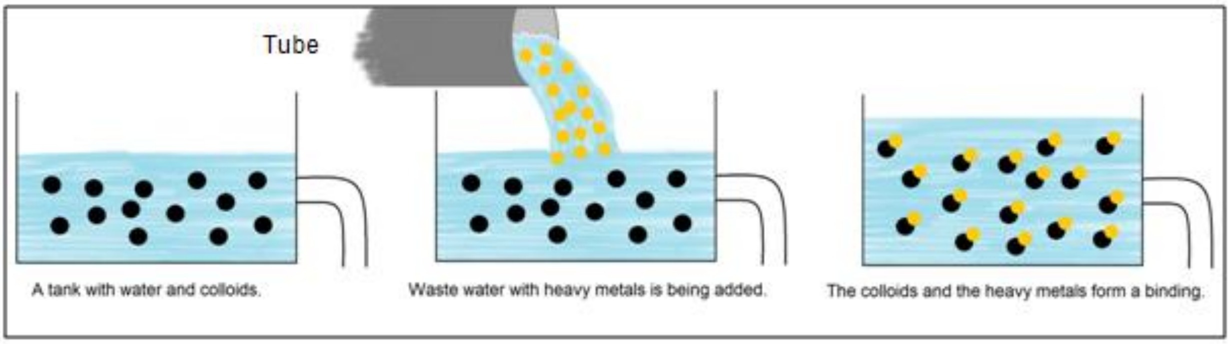
Copper can disturb the activity in soils, as it influences the activity of microorganisms and earthworms negatively. As a result of that the decomposition of organic materials can be seriously slow down.

Zinc:

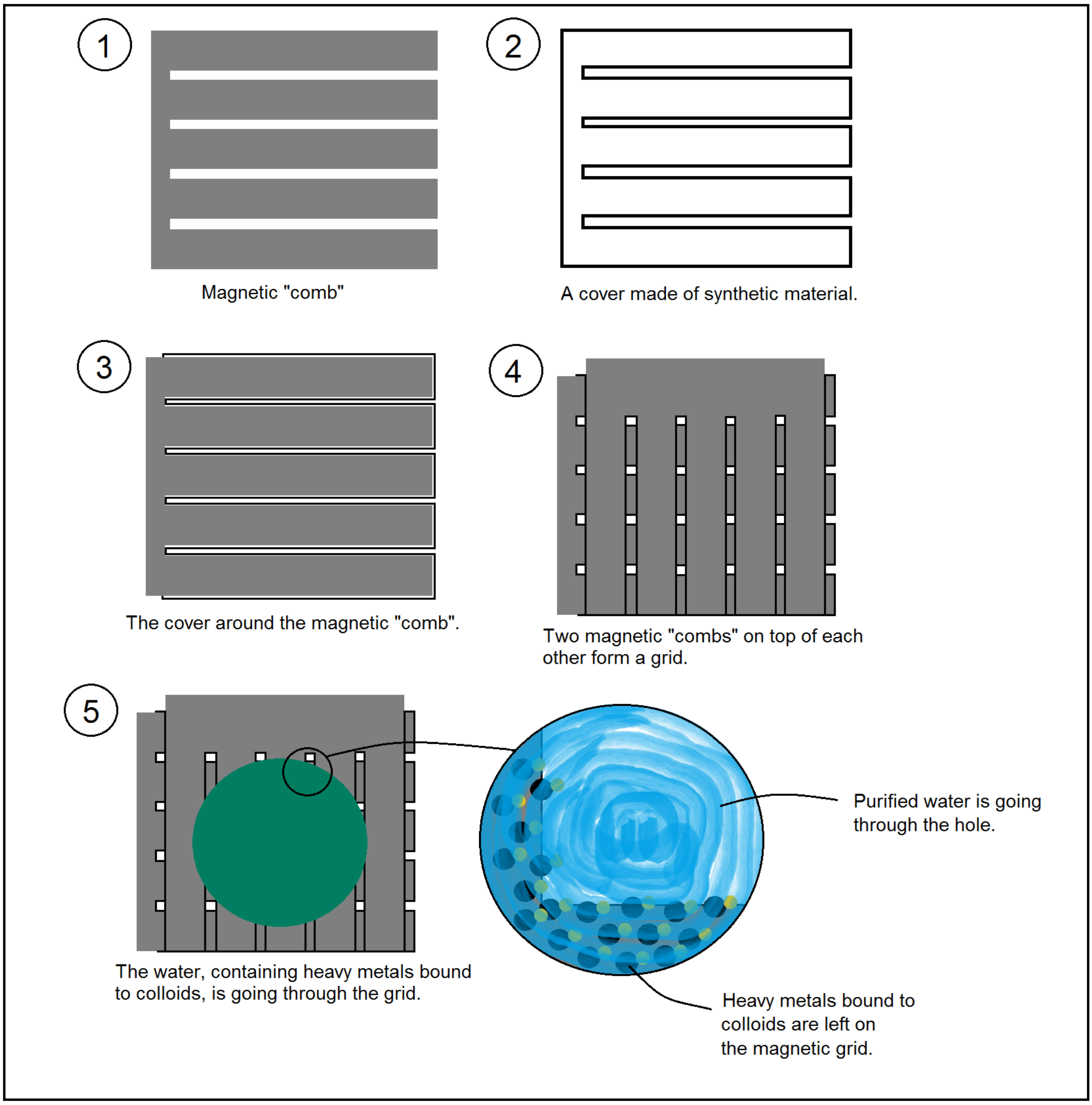
Zinc (in small amounts) is an essential requirement for a good health. However, excess zinc can be harmful. Excessive absorption of zinc suppresses copper and iron absorption. Toxicity by zinc can occur in acute and chronic forms. Acute disadvantageous effects of the intake of high zinc concentrations include nausea, vomiting, loss of appetite, stomach cramps, diarrhea, and headaches. Zinc ions in a solution can even cause harm to plants, invertebrates, and vertebrate fish.

Appendix D: Purification System

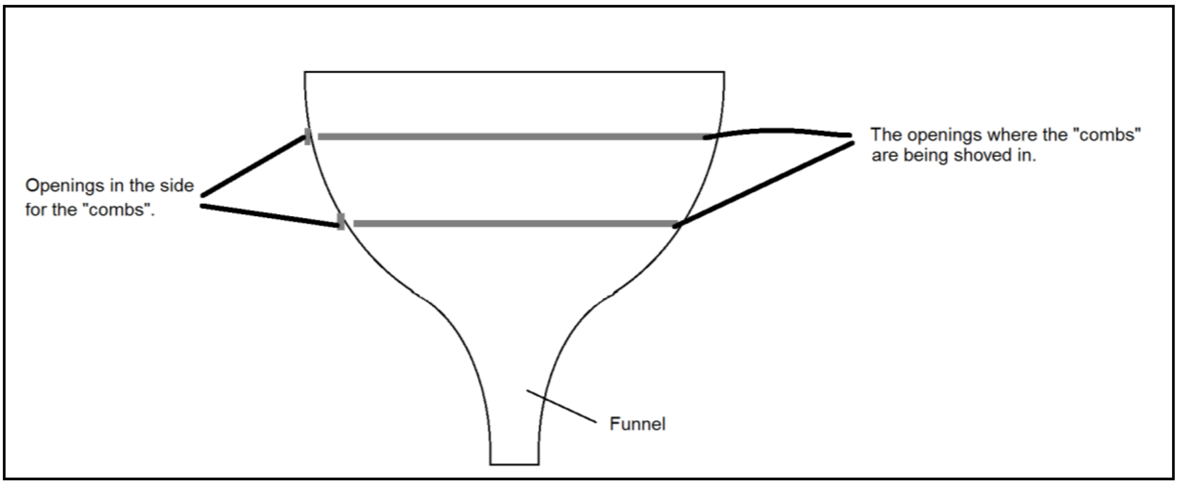
Part one of the system: the tank



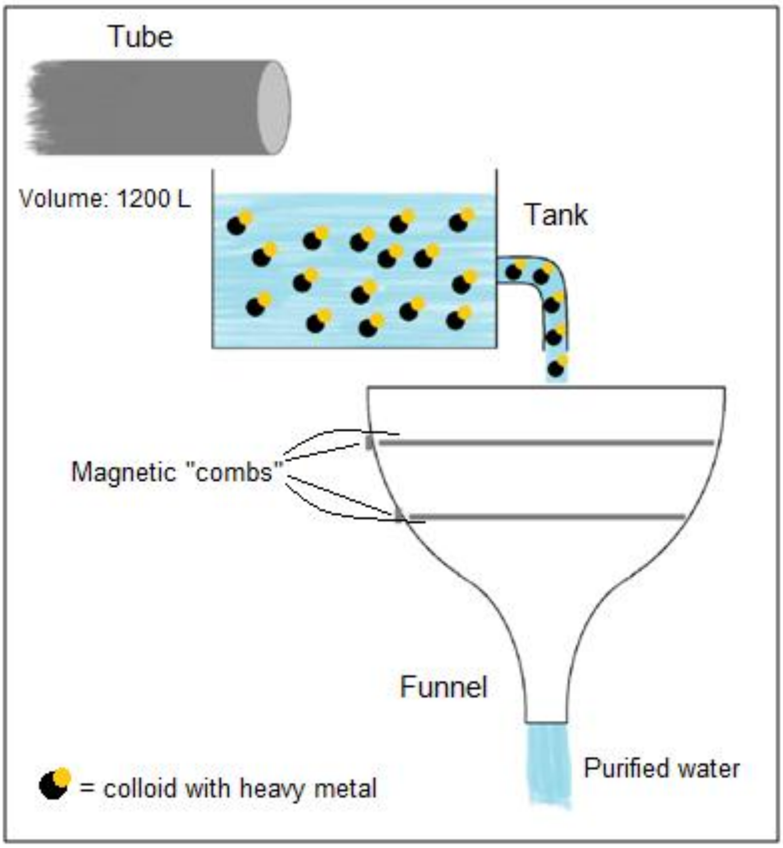
Part two of the system: the grids



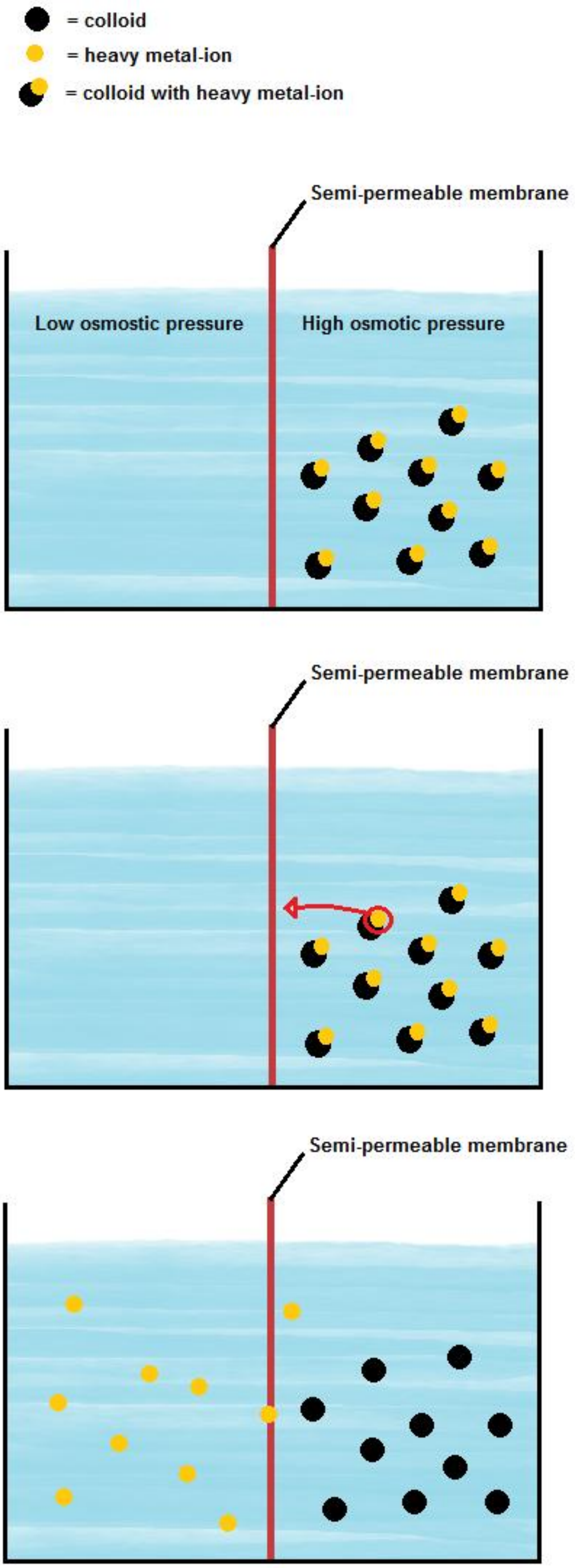
Part three of the system: the funnel



Part one, two and three put together



Appendix E: Separating Colloids and Heavy Metal-ions



Appendix Experiment University Utrecht

Synthesis of maghemite

For the synthesis of maghemite, initially Iron(II) chloride tetrahydrate ($FeCl_2 \cdot 4H_2O$) and Iron(III) chloride hexahydrate ($FeCl_3 \cdot 6H_2O$) need to be used. When these particles are being composed with a base (OH^-), the following chemical reaction takes place:

$2\ Fe^{3+} + Fe^{2+} + 4\ OH^- \rightarrow Fe_3O_4 + 4\ H^+$

Fe_3O_4 is also a ferrofluid (magnetite). When you want to make maghemite, a lot more work needs to be done.

Let's take the example that 3.9 magnetite needs to be made. On the basis of the chemical reaction the molar ratio can be determined.

$2\ Fe^{3+} + Fe^{2+} + 8\ OH^- \rightarrow Fe_3O_4 + 4\ H_2O$

The molar ratio of Fe^{3+} : Fe^{2+} : Fe_3O_4, will be 2 : 1 : 1.

With these information the amounts of Iron(II) chloride tetrahydrate and Iron(III) chloride hexahydrate can be calculated:

Fe_3O_4: 3 x 55.85 + 4 x 16 = 231.55 gr/mole

mole	1	?
gram	231.55	3.7

➔ ? = 3.7 / 231.55 = 0.016 mole Fe_3O_4

There is 0.016 mole Fe_3O_4 so there also is 0.016 mole Fe^{2+} and 0.032 mole (2 x 0.016) Fe^{3+} according to the molar ratio.

$FeCl_2 \cdot 4H_2O$: 55.85 + 35.45 x 2 + 4(18.02) = 199.39 gr/mole

$FeCl_3 \cdot 6H_2O$: 55.85 + 35.45 x 3 + 6(18.02) = 270.296 gr/mole

mole	1	0.016
gram	199.39	?

➔ ? = 0.016 x 199.39 = 3.19 gr $FeCl_2 \cdot 4H_2O$

mole	1	0.032
gram	270.296	?

➔ ? = 0.032 / 270.296 = 8.65 gr $FeCl_3 \cdot 6H_2O$

1. Weigh the quantities $FeCl_2 \cdot 4\ H_2O$ (3.19 gr) and $FeCl_3 \cdot 6\ H_2O$ (8.65 gr) and transfer the material into a 500mL graduated cylinder. Add 360ml distilled water and stir until dissolved. Make up to 380ml with distilled water. Transfer the solution in its entirety to a 500mL two-neck round-bottom flask. The mixture has a dark orange color.
2. Stir a solid salt solution, and then add 25 ml ammonia (25% NH_3 (aq)) to. There will form a dark precipitate, which is magnetite (Fe3O4). When adding ammonia, the solution has immediately been pitched black. The magnetic force can be felt.
3. Bring the magnetic precipitate together using a magnet. Remove the supernatant (supernatant), by decantation (via the left-hand side of the flask). The particles should have gone to one side, otherwise it may not be drained. After about 4 to 5 minutes, the magnet and the magnetic substance are therefore strong enough to be drained. Loss of magnetite is not that big of problem. Keep a tissue handy for any spillage.
4. Add to the precipitate 40ml of 2M HNO_3, to disperse (fine distribution in the liquid). Let it stir for 5 minutes. Go ahead with the next step.
5. Make 60 ml of a 0.35 M iron (III) nitrate solution. Solve hereto 8.48 g Fe (NO_3) 3 • 9 H_2O in 50m demineralised water. When everything is dissolved, make up to 60ml. The color of the mixture is orange.
6. Add the ferric nitrate solution to the reaction mixture. Heat the reaction mixture to about 90 ° C for 1 hour under reflux conditions. The magnetite will oxidize to maghemite. The maghemite is red in color. The color of the mixture has also become red.

7. Bring the maghemite together using a magnet (for a few minutes), and then remove the supernatant. The suspension is "transparent" orange. By the magnet it is darker, because all the magnetic particles are around there.
8. Wash the precipitate twice with 100 mL 2M HNO_3 and remove as much as possible (use the magnet). Redisperse the sediment by the addition of about 50mL deionized water. Make sure the 'transparent' (unscattered) black / red dispersion is obtained and not the murky yellow-brown suspension.

Coating of maghemite with oleic acid

1. Dilute 2mL (using a Finn pipette) of the aqueous dispersion with 50mL distilled water in a 250ml two-neck round-bottom flask. Let the maghemite particles clump together (aggregate) by the addition of a few drops (4 drops) ammonia (25% NH_3 (aq)). Obvious particles are created (precipitation).
2. Let the aggregates completely sediment using a magnet (this takes about 3/4 minutes) and remove the supernatant. The colloids are quickly attracted to the magnet. The color of the mixture turns orange.
3. Wash the sediment once with 50mL distilled water, add 100 mL distilled water. Stir until everything is dispersed. When washing the dirt comes off of the colloids. With us it stayed a bit clumped together, if that happens you have to slightly spread it with the magnet.
4. Now add 6 to 8ml oil acid (13ml oleic acid per gram maghemite). The maghemite particles shall migrate within a few seconds of the water phase to the oil .The oil is obvious to see in the mixture (oil spills). Many particles are trapped in the oil. Oil wants to be with oil, so it results in a large drop. The rest is clear. The particles are therefore now in the oil phase.
5. Remove the oil phase of the colorless aqueous phase using a separating funnel. The colorless lower layer is thus removed, and the upper layer of maghemite in the oil phase remains. Collect the oil with maghemite particles in a two-neck round-bottom flask of 50ml. Then wash the oily liquid three times with 12ml of ethanol so water and the surplus of oleic acid are completely eliminated.
6. Dry the product carefully with nitrogen gas. Ensure that all of the ethanol has evaporated. Into the product cracks arise after drying. The flask is very cold, it is because energy is required for the evaporation of ethanol (endothermic reaction). This energy is taken from the energy of the flask.
7. Disperse the maghemite particles (coated with oleic acid) in, for example 0.75 mL cyclohexane (C6H12). Using cyclohexane as a solvent, a stable colloidal dispersion is obtained.