MODELING LAND USE AND WATER QUALITY MANAGEMENT SCENARIOS FOR THE UPPER CITARUM RIVER, JAVA, INDONESIA

MASTER THESIS
CIVIL ENGINEERING AND MANAGEMENT
UNIVERSITY OF TWENTE

R. Venema BSc
4-12-2015

UNIVERSITY OF TWENTE.

Modeling land use and water quality management scenarios for the Upper Citarum Basin, Java, Indonesia

Master thesis
In Civil Engineering and Management
Faculty of Engineering Technology
University of Twente

Author	Rigt Venema BSc	
Contact	r.venema.jr@gmail.com	

Location and date	Enschede, December 4, 2015	
Thesis defense date	December 11, 2014	

Graduation Committee		
Graduation Supervisor	Dr. Ir. D.C.M. Augustijn	University of Twente
Daily supervisor	V. Harezlak MSc.	University of Twente
External supervisor	Dr. G.W. Geerling	Radboud University Nijmegen, Deltares

Front picture	The Guardian

ABSTRACT

The Citarum River is one of the most polluted rivers in the world. The main reasons for the impaired water quality are the high population density and the rapid industrialization in the catchment. Because of the size and variety of the problems in the Upper Citarum Basin, the high poverty levels and an under-resourced government, the relevant institutions lack overview of how best to react to the problems.

The goal of this research is to determine relevant scenarios and calculate the effect of these scenarios which give stakeholders a handhold on what measures are most effective. These scenarios are based on alternative land use and water quality management as suggested in interviews with involved stakeholders and have the purpose to lower the concentration of pollutants in the river compared to a reference scenario based on the current situation. The changes in concentration for the different scenarios are modelled by a one-dimensional hydrodynamic and water quality model (SOBEK).

In the interviews the stakeholders were asked to pinpoint the problems and associated solutions for the impaired water quality in the Upper Citarum Basin related to agriculture (crop growing and animal husbandry), industry and households. These solutions are combined in scenarios and the effects on water quality are quantified for the substances COD, BOD, nitrate, sulphate, zinc and fecal coliform. These substances characteristic emissions of the land use types mentioned before.

The current status of the river is used as reference scenario for comparison with the other scenarios. The current status is determined by using data sets of PJT-II (an organization responsible for measuring the water quality). The measured concentrations are averaged per monitoring station per season (wet and dry). The average concentrations for most substances and at most places are much larger than the maximum permissible concentrations. From the monitoring data it is not clear what the sources of the different substances are. This information is needed to determine the changes in emissions for the different scenarios. Therefore the emissions from crop growing, stockbreeding, industry and households are estimated and compared to measured concentration to verify the reliability of the estimated emissions.

The scenarios determined based on the interviews are:

Reference scenario	The current status in 2015 is used as basis scenario
Worst case scenario 2030	An autonomous growth of population and economy without interventions to prevent emissions is taken as the worst case scenario
Improved sanitation	People without any sanitation facilities are provided with a septic tank
Livestock in communal barns	The dispersed cattle is concentrated on a few places in large barns and the manure is used for other purposes such as biogas production to control the emissions
Changing crops	The paddy fields are changed into fields for dry crops
Changing industry	This is evaluated by three sub scenarios. First is evaluated what happens if the industries have zero emission to the river; secondly if the emission of only the textile industry is reduced to zero; and third if the textile industry is converted to other types of industry

The scenarios lead to changes in emissions to the river. Together with a fixed discharge for the wet and the dry season, this is used as input for the SOBEK model to determine the concentration at the end of the Upper Citarum Basin (Nanjung). The calculated concentration is compared to the reference scenario to evaluate the change in concentration

For all scenarios except the worst case scenario, the water quality overall improves. Based on the results, providing septic tanks to people without any sanitation is the most promising scenario. This leads to the biggest drop for BOD, COD and fecal coliform. The biggest drop in nitrate is when the cattle is hold in communal barns. The scenarios involving change in industry causes that most of the substances decrease, except zinc. Zinc increases because of an increase in factories which emit zinc. The scenario involving the change of crops, has no significant effect on the water quality.

The results show that although measures will lead to an improved water quality, the maximum permissible concentration is still not in reach. This means that the measures in the separate scenarios are not enough to get the river clean enough. However it gives an idea of the effect of the different measures. Combining the measures (e.g. septic tank, communal barns, change industries) in the scenarios can lead to a water quality below the maximum permissible concentration (not calculated in this research).

PREFACE

This documentation is the final part of my study Civil Engineering and Management at the University of Twente. Finishing this, means finishing my period as student. This thesis tries to give the different stakeholders a handhold how to start to improve the water quality by combining their solutions for the water quality problems in scenarios. It is part of the PhD project of Lufiandi. I started this graduation project in February of 2015 with a month visiting the area of interest in Indonesia. During this month I talked with stakeholders and looked around in the area. This gave me insights which I did not get when I stayed the whole period in The Netherlands. It also made my project more alive for me, to see the real problems and gave me energy to finish it.

First of all, I would like to thank my supervisors for their advice and feedback: Denie Augustijn, Valesca Harezlak, and Gertjan Geerling. Denie, thank you for your detailed feedback and guidance during the process. You always knew to ask the questions I had not researched and by doing so adding more depth in my research. Valesca, I want to thank you for your help with the model and the feedback you gave. When I had questions about the model you always took the time to answer them carefully. Gertjan I would like to thank you for the opportunity and trust you gave me to do this research and for the arrangements you made for my stay in Indonesia. Also your enthusiasm during our talks gave me energy to research more and go deeper into the matter.

Special thanks to Lufi and Tya. Tya, thank you very much for your help in calculating the emission from agriculture. Lufi, I would like to thank you for your help, feedback and discussions we had during the process. Even more I would like to thank you for the time in Indonesia. You took me out to see Bandung, you arranged the meetings with the stakeholders and showed me the important parts of the basin. I really appreciate that.

Furthermore I would like to thank my friends for their support, great discussions and memorable events. I had great time at the university.

Last but not least I want to thank my family for giving me the opportunity to study and of course their support. Pap en mam, bedankt voor alles!

Rigt Venema

Enschede, December 2015

CONTENTS

1 INTRODUCTION

This Chapter addresses the outline of the research. First the study area and the problems will be discussed, followed by the research questions and methodology.

1.1 Citarum River

The Citarum River, 269 km long and draining an area of 12,000 km^2, is one of the largest rivers on Java (Indonesia). It originates from Mt. Wayang and flows through the middle of the western part of the island before flowing into the Java Sea (Figure 1). The basin has an average annual rainfall of 2300 mm, and the annual discharge at Nanjung (near the first reservoir) in the dry season is around 30 m^3/s and in the wet season a tenfold (310 m^3/s). The river accommodates the need for water of nearly 35 million people, is an important source of water for the central part of Java and supplies 80% of the water demands of Jakarta (World Bank, 2013). The river plays a vital role in the economic development and livelihood of the people by supporting agriculture, fisheries, hydroelectric power generation, public water supply and industries of West Java Province and Jakarta City (Sahu et al., 2012). It sustains 20 percent of Indonesia's gross domestic product (Collins, 2009). In contrast, the Citarum River is ranked by different sources as one of the most polluted rivers in the world (Mangan, 2014). It is called the 'Rainbow' river because there are a lot of textile factories on the river banks which discharge their used chemicals in the river (Groenink & Schuurman, 2014).

FIGURE 1 LOCATION OF THE CITARUM BASIN IN INDONESIA AND THE STUDY AREA WITHIN THE BLACK CIRCLE, THIS IS UPSTREAM THE FIRST RESERVOIR (BIG: GOOGLE MAPS, SMALL: (ADB, 2013))

1.2 Study area

The Upper Citarum Basin is the part of the Citarum River upstream of the first reservoir (Saguling, Figure 1). The Upper Citarum Basin is a large valley surrounded by mountains and volcanoes (Figure 2). It lays approximately 800 meters above mean see level (Prihandrijanti & Firdayati, 2011). It contains around 20 tributaries to the Citarum River, which flow from the mountains to the lowest part of the basin. The basin has an area of 4,800 km^2 and is home to roughly eight million people (Fares & Yudianto, 2003). The basin contains two city districts: Bandung and Cimahi. Bandung is the third largest city of Indonesia with approximately 2.5 million inhabitants, Cimahi has around 600,000 inhabitants.

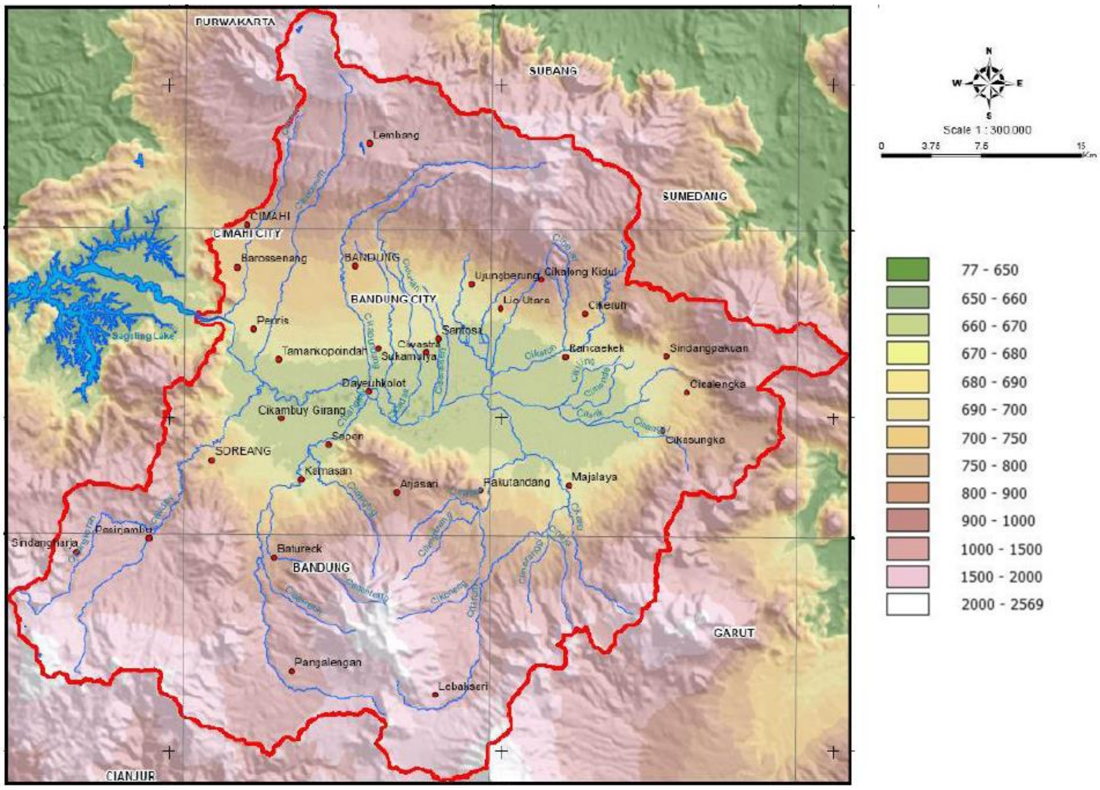


FIGURE 2 ELEVATION MAP OF THE STUDY AREA WITH THE FIGURES IN METER ABOVE MEAN SEA LEVEL (DELTARES, 2011)

1.3 Land use types

In the Upper Citarum Basin several land use types can be discerned. In Figure 3 the land use distribution in the basin is shown. It shows the city of Bandung and Cimahi as a large conglomerate in the north west of the basin with agricultural fields (rice fields and plantations) around it. The few pieces of forests and bushes left, are located in the south of the basin near the mountains. The industry clusters are spread throughout the basin and are all adjacent to a river for water supply.

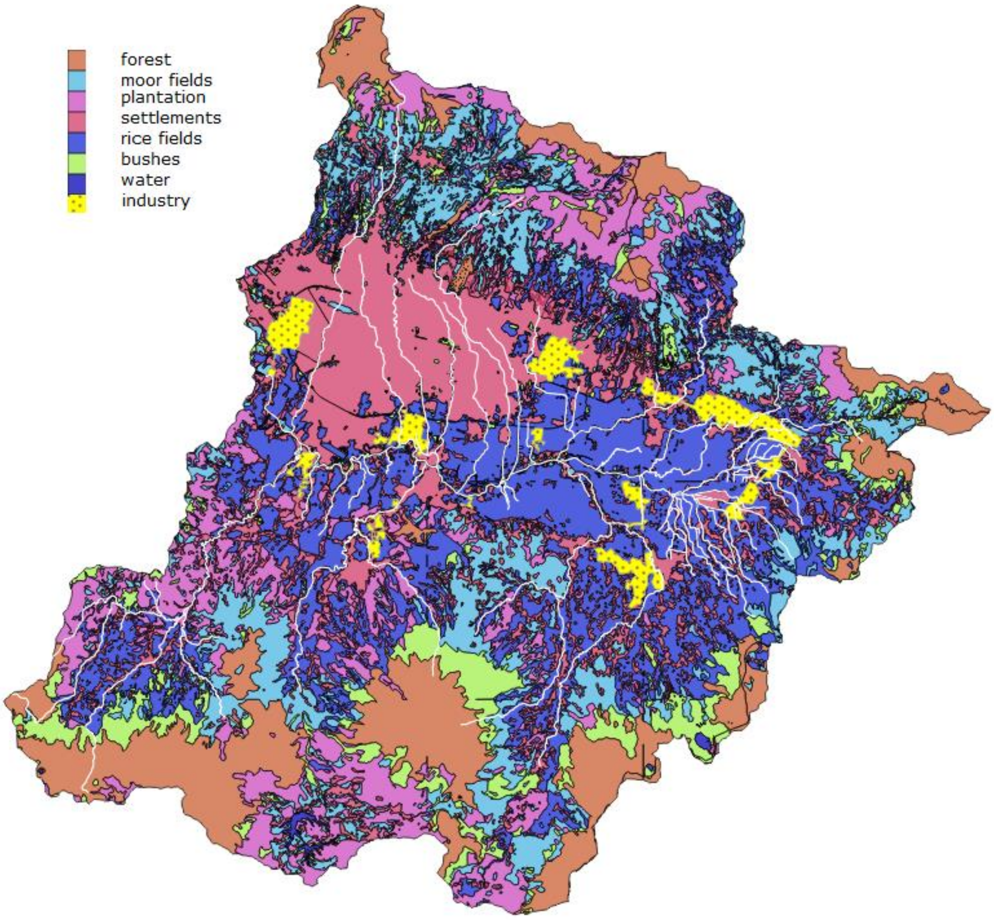


FIGURE 3 LAND USE TYPES IN THE UPPER CITARUM BASIN

1.4 Problem Definition

The main reasons for the impaired water quality are the high population density and the rapid industrialization in the catchment of the Citarum River. The water of the Citarum River is used for consumption and to irrigate the lands, so a polluted river is a hazard for people's health and a threat to the food production. The chemicals used in industries, the pesticides and nutrients in agriculture, and human waste are discharged or are seeping into the river (Fulazzaky et al., 2008).

The size and variety of the problems in the Upper Citarum Basin and an under-resourced government are the cause that the relevant institutions have a limited overview of how best to react to the problems. A consequence is that the people living in the Citarum River Basin are not aware of or are not given any alternatives to get clean water from and to dispose their waste water to.

1.5 Research Objective and Questions

The problem definition leads to the following goal of this master thesis: Define alternative land use and water quality management scenarios based on solutions suggested by stakeholders and quantify the effect of these scenarios on the water quality. The results of this study should give the authorities insight in which measures are most effective in improving the impaired water quality.

The objective of this research leads to the following main question:

What are possible alternative land use and water quality management scenarios and their effects on water quality in the Upper Citarum River?

To answer this main question, some sub questions have to be answered first:

1. What are, according to the different authorities, the causes of and possible solutions for the impaired water quality in the Upper Citarum River? (Chapter 2)
2. What are the estimated loads and resulting concentrations of the most relevant substances to the Upper Citarum River? (Chapter 3+4)
   - 2.1 What are the most important substances that cause the impaired water quality in the Upper Citarum River based on water quality data? (Chapter 3)
   - 2.2 What are the monitored concentrations of the relevant substances? (Chapter 3)
   - 2.3 What are the loads based on estimations of emissions from different types of land use? (Chapter 4)
   - 2.4 How do the concentrations derived from the estimated loads compare to the measured concentrations? (Chapter 4)
3. What are suitable scenarios for the Upper Citarum River Basin and the associated changes in loads? (Chapter 5)
4. What are the most promising scenarios based on their effect on water quality? (Chapter 6)

1.6 Research outline and methodology

The outline of the research is represented schematically in the research model below (Figure 4).

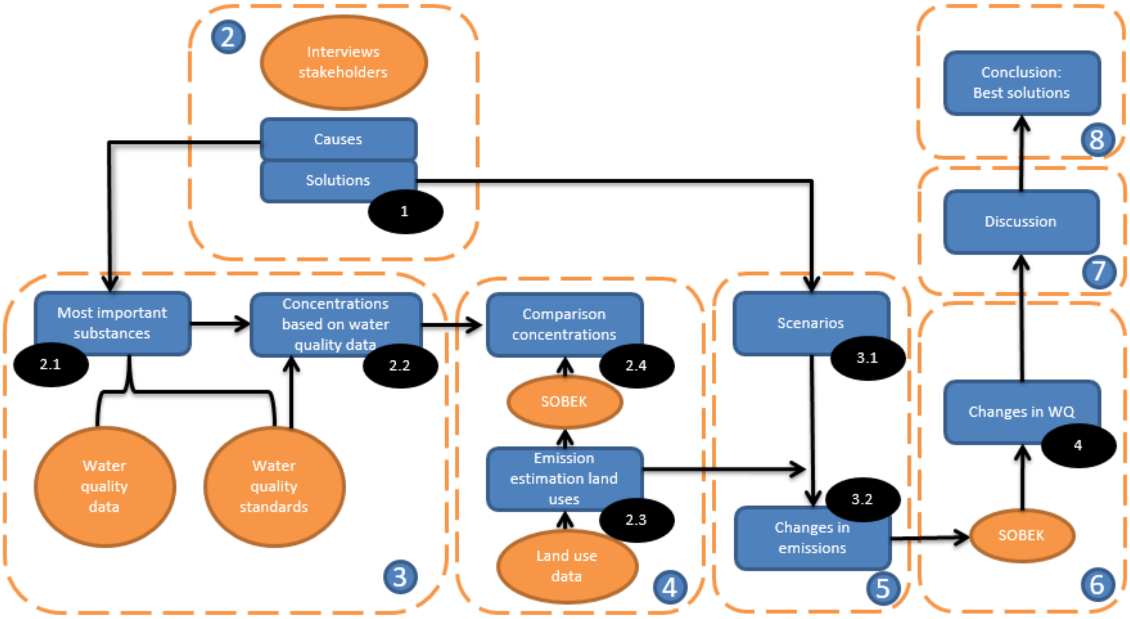


FIGURE 4 RESEARCH MODEL OF THIS STUDY. THE BLACK NUMBERS ARE THE RESEARCH QUESTIONS AND THE BLUE NUMBERS ARE THE CHAPTERS IN WHICH THE CORRESPONDING PARTS OF THE RESEARCH ARE COVERED.

In Chapter 2 the interviews with relevant stakeholders are elaborated. In the interviews the stakeholders were asked to give their opinion on what the main causes and the associated solutions are for the impaired water quality in the Upper Citarum Basin. The answers of the stakeholders are used, together with the available water quality data and water quality standards, to determine the most relevant substances (Chapter 3). Thereafter, the concentrations of these substances will be evaluated to get a representative overview of the water quality status in the Citarum River. Typical concentrations will be derived for wet and dry conditions to use as verification for the model simulations later on.

To get an independent estimation of the emissions to the river, the emissions of different land use types are estimated based on data for various characteristics of the land use type (Chapter 4). These emissions are used as input for the SOBEK model, a hydrodynamic model developed by Deltares which also include a water quality module (D-Waq). The model is run for stationary conditions. The resulting concentrations of the estimated emissions will be compared to the measured concentration to evaluate the reliability of the estimated emissions. The model is then used to evaluate different land uses and water quality management scenarios. These scenarios (Chapter 5) are based on the suggested solutions by the stakeholders. The scenarios lead to a change in emissions which are used as new input for SOBEK to quantify the corresponding concentrations (Chapter 6). The results will be discussed and conclusions will be drawn on what the most effective scenarios are to improve the water quality.

2 CAUSES AND THEIR SOLUTIONS IN CITARUM BASIN

In this Chapter the causes of the impaired water quality in the Upper Citarum River and their solutions are elaborated according to different stakeholders in the Upper Citarum Basin. The input from the stakeholders is used to develop scenarios. The stakeholders interviewed were people from the local, provincial and national government which have authority on water quality; a non-governmental organization (NGO) which tries to raise awareness of the problem in the Citarum River; and an organization for the water quality managers of the industry. These interviews were held in Indonesia face to face and consisted of two questions:

1. What are the main causes of the impaired water quality per land use type?
    a. Crop growing
    b. Animal husbandry/stockbreeding
    c. Domestic
    d. Industry
2. What are the main solutions to improve the water quality per land use type?

The answers of the different stakeholders are compared and overlapping answers are combined in scenarios. Remarkable was that stakeholders gave a lot of comparable answers, therefore no distinction is made in the text between stakeholders.

2.1 Crop growing

A large problem with the cultivation of crops is the erosion of the fields. Land is scarce, forcing farmers to cultivate hills. On the hills the trees are cut down and dry crops (maize, wheat, etc.) are planted. Dry crops do not need a lot of water (in comparison to rice), so the lands are shaped in such a way that water runs down quickly otherwise the crops drown in too much water taking along the pesticides and fertilizers used. A negative effect caused by the cultivation on this is erosion (Nibbering, 1999). The sediment flows into the river and causes a very turbid river.

FIGURE 5 THE FARM LANDS ON THE HILLS WITH SPURS FROM CREST TO TROUGH (VENEMA, 2015)

This erosion can be countered by planting crops which have a live span of several years: the roots grow into the ground which protect the hill, lands are not plowed anymore to get the soil loose for new crops, and foliage covers the ground so the rain does not dislodge the soil. Crops with a longer live span are fruit trees, coffee plants and tea plants (Nibbering, 1999). However, the land is owned by business men who want to make fast profit. Planting perennial crops results in no profit in the first few years because the plants should grow first before they can be harvested (French, 1986; Hyde & Seve, 1993). A solution according to the stakeholders is compensation for the lost profits from the government for the farmers/business men who do switch to long lasting crops.

Another problem in agriculture is the use of fertilizers and pesticides. More usage results in more runoff of fertilizers and pesticides to the river. The farmers are not aware of the effect of the application of too much fertilizers and pesticides. They think that applying more gives them a better yield. Also contracts exist between farmers and producers of fertilizers and pesticides. These contracts force the farmers to buy a minimum amount of fertilizers and pesticides a year; which the farmers in their turn, apply all on the land. A third problem is the use of illegal fertilizers and pesticides. These products contain high concentrations of dangerous substances. However the farmers think that the use of these illegal products gives them a higher yield than some legal products so they use illegal products. A large producer of an illegal pesticide is a state owned enterprise. The government wants a high yield of the fields, because that enhances the prosperity. Therefore they allow the use of it. On the other hand they have made the use of this pesticide illegal (Craswell & Karjalainen, 1990; Llewelyn & Williams, 1996).

To counter the problems of fertilizers and pesticides the farmers should be trained in using them properly. In educational programs the farmers should be taught on how much fertilizer and pesticides they should use for a certain crop; what the effects are of the use of too much fertilizers and pesticides; the existence of organic products (e.g. manure of livestock) and natural enemies for certain threats for the plants. All this is to reduce the use of industrial produced fertilizers and pesticides (van den Berg & Jiggins, 2007; Feder, et al., 2008; “Nilaparvata lugens,” 1996).

According to the interviewees from the government, the government should be responsible for the education of the farmers. The government should start a program to educate the farmers or even retrain the farmers into another job, to decrease the amount of farmers. Besides this, the government has to hire more inspectors to inspect the farmers on the use of fertilizers and pesticides and on illegal farming in protected forests. And lastly, the government should be consistent in its regulations. Now an illegal pesticide is produced by a state owned enterprises. This should be stopped in order to reduce the use of this illegal pesticide (Konradsen et al., 2003).

2.2 Animal husbandry

According to the different interviewees the problem for water quality with animal husbandry is the direct discharge of manure into the river (Widodo et al., n.d.). The animals are kept in barns near the river so when the farmers clean the barn this waste flows directly into the river (Figure 6). There is no animal waste collecting system or a practice of using the manure as fertilizer on the land. Besides the animals in barns, the majority of the animals walk on the lands. This leads that with the run off of rain water the pollution is taken to the river.

FIGURE 6 COWS IN A BARN WHERE THE RIVER IS DIVERTED THROUGH (VENEMA, 2015)

The government has started to build biogas and compost facilities where manure can be transformed to usable gas and fertilizer. However, a few of these facilities do not work anymore because of mismanagement and because the users (farmers) are not educated by the government on how to use the facilities properly. Other facilities are not in use because there is not enough manure to keep the facility working. The farmers live spread over the area and the transportation of manure to the facilities is not taken care off. Another problem is that the facilities are imposed to the communities by the government without checking the willingness among the community. The community is not inclined to maintain the facility (Bond & Templeton, 2011).

A solution, according to the stakeholders, is to relocate the animals to a communal barn. The animals are put together, so the waste can be collected easily. An additional advantage is that biogas and compost facilities have a constant supply of manure, which is a condition to let the facilities work properly.

As described in section 2.1 the education of the farmers is a solution to the problem. Also in this case educating the farmers on how to use the biogas and compost facilities properly, making them aware on the consequences of discharging the manure, and the usage of manure as fertilizer, is part of the solution.

2.3 Domestic waste

The problems of domestic waste can be divided into two categories: solid waste, and grey and black water. The solid waste consists out of everyday items which are discarded by the public (garbage) like plastics, bottles, wood, etc. The grey and black water is the waste water coming from households like washing and toilets. In this research the focus is mainly on dissolvable fluids so the solid waste is not taken into account.

2.3.1 Grey and Black water

52.5 percent of the people in the Bandung area is connected to a waste water treatment plant and 22.5 percent has a septic tank (individual or communal), this means that 25 percent has to find another way to dispose their waste (Imhof & Mühlemann, 2005). In the rural areas even less people have a connection to some sort of sanitation (Almy, 2008). People dispose their waste by dumping it in the rivers or on the open field. However, even when people have a form of sanitation this does not mean that this waste water is fully treated. The sewage systems are old and there is leakage to the surface and ground water. Also the waste water treatment plants are not up to date and because they are situated in a low lying area, the plants are flooded once in a while (Prihandrijanti & Firdayati, 2011). Some of the septic tanks used are leaking, but the biggest problem here is that there are not enough trucks available to empty the septic tanks. The people empty their tanks by simply discharging it to the drainage system. Besides this, it happens that the truck drivers do not empty their trucks at the assigned waste water treatment plants, but dump it in the river and keep the money paid by the homeowners.

The lack of waste water treatment plants (WWTP) and septic tanks is the cause of a large part of the problems with grey and black water. Constructing more sewage systems and WWTPs on a community level is, according to stakeholders, the solution.

2.3.2 Overlap in domestic problems

The government has a budget for collecting and processing solid waste and this same budget is for the treatment of grey and black water. This budget is not sufficient for fully collecting and processing both the solid and the liquid waste. The government therefore has to make a decision in what is collected and treated. The solution is raising the budget, so the government can collect and treat both solid waste and grey and black water.

Another problem is the development of the river banks. In the city of Bandung it is illegal to live within ten meters of the river bank. In the rural areas this is even fifty meters. Poor people do not have any place else to live, because of the crowded city, and therefore they build their houses in the illegal zone near the river bank. These people do not have any sanitation facility at their disposal because when the government facilitates a waste collecting system in these illegal areas, the government indirectly allows the people to live there.

The solution to encounter the development of the river banks is to relocate the people elsewhere and be strict in the enforcement of the law. By relocating the people living there the river banks are depopulated again and by enforcing the law, people are not settling there anymore.

A lot of people are not aware of the dangers of a heavily polluted river. The government should start a program to educate the people of the dangers of the usage of the polluted water and what the effects are when they throw their solid waste and discharge their grey and black water into the river.

2.4 Industry

The industry can be divided into two categories: registered and unregistered. The registered industry is registered by the government and needs to obey regulations on the maximum amount of effluents discharged. When a company wants to register as legal industry, they have to proof that their emissions are within standards before getting a permit. So before getting a permit, the industry has to produce already. Therefore, there are also a large number of unregistered industries.

2.4.1 Registered industry

The registered industries are obliged to treat their water until it is within standards (Appendix A). Most of the registered industries have some sort of waste water treatment, but it costs money to run it. Therefore some managers of the industry choose to only treat the water when they expect an inspection. The rest of the time they discharge the waste water directly to the river without treatment. The water quality managers of these industries, who are responsible for the water treatment, take (according to the organization on water quality managers) a passive role and obey what the bosses tell them to do.
Besides this, the technology used in the WWTPs (both owned by the industries as the communal ones) is not advanced enough to filter all the different substances from the waste water. The existing plants in Indonesia are for example not equipped to filter heavy metals. So even when the water is treated, the effluent is not within standards.

The problem of the waste water treatment can be tackled by building more WWTPs and even centralize the waste water treatment for the industry so there is more control in the quality of water after treatment. Building new WWTPs gives also the opportunity to improve treatment technology so the heavy metals are also filtered out of the waste water.

2.4.2 Unregistered industry

The unregistered industries are the majority of industries in the Upper Citarum River Basin. The West Java EPA estimates that there are 1500 industries in the basin of which 400 registered. The unregistered industry mainly consists out of micro and small industries (home shops, little workplaces, etc.). The unregistered industries have no permit yet or are not within standards and thus have no rights to a permit. These industries often are hiding in communities who support the presence of the industry because these industries provide jobs.

2.4.3 Joint problems registered and unregistered industry

The monitoring whether the industries are handling within limits is taken care of by the government. The authorities in Indonesia are unfortunately not very powerful, so the amount of inspectors to check the industries is due to low budgets limited. Besides this, when an inspector catches an industry in flagrante delicto, the penalties are lower than building and operating a waste water treatment plant. Therefore the industries prefer to pay the penalties.

A solution is raising the budget, which is easier said than done, because of a poor government. This leads to more inspectors and a better law enforcement, to force the industries to treat their water, are necessary to improve the water quality. Higher penalties can be deterrent and a way to enforce the rules more.

A large problem is the duality of the problem. The industry improves the employment in the country because the rules are not that strict so foreign investors open their businesses in Indonesia. On the other hand, when Indonesia tightens its rules, the owners of industry easily move their companies to other countries where the rules are not that strict. This causes unemployment. Therefore the government of Indonesia has a dilemma. A choice for the environment is a risk of increased unemployment and a choice for employment has the risk for an increase in pollution discharged.

Another way to give the industry a message that they have to improve their waste water treatment is to develop a classification system for their products. For example putting an extra label inside clothing which shows the public how polluting the manufacturer of the product is. Hopefully the public will only choose the products which are good for the environment and in this way force the polluting industry to treat their water properly.

2.5 Overview

In Table 1 an overview is given of the outcome with the stakeholders. It is tried to give per problem solutions. These are next to each other in the columns.

TABLE 1 SUMMARY OF THE PROBLEMS AND SOLLUTIONS IN THE CITARUM BASIN

Land use type		Problems	Solutions
Agriculture		- 'Vertical paddy fields' causing erosion - Turning forests into farmland	- Replanting trees on hills (fruit/tea/ coffee)
		- Wrong crops at the wrong places	- Educate farmers on what to cultivate where
		- Application of too much fertilizers/ pesticides - Application of illegal fertilizers/ pesticides	- Use organic fertilizers and pesticides - Educate farmers on how to use fertilizers and pesticides
		- Government with two agendas	- Government has to be consistent in regulations
		- Land owned by business men	- Compensation of lost revenues in the years when trees are growing
		- Farmers have contracts with producer of fertilizers/pesticides to purchase a certain amount	- Retraining of farmers - More inspectors
Stockbreeding		- Manure directly discharged to the river	- Make farmers aware of consequences of discharging manure to river
		- Biogas/compost facilities are designed for large amounts of manure - No manure collecting system - Farmers are spread over the area	- Communal barns - Build more biogas/ compost facilities
		- Existing facilities do not work anymore - Farmers are not educated to work with biogas/compost facilities - Lack of willingness among the community	- Educate farmers how to use biogas/compost facilities
Domestic Waste	Solid waste	- No regular waste collecting	- Separated collection of waste (organic/inorganic) - Build incinerators - Reduce, Reuse, Recycle (government as role model)
	Grey/Black water	- Leaking septic tanks - Not enough trucks to empty septic tanks - Corrupt truck drivers - Leaking sewage system	- Build more septic tanks and WWTPs - Community based WWTP
	Common	- People living within 10 meters of the river bank	- Make people aware of dangers
		- Government has limited budget for sanitation	
Industry	Registered	- Passive water quality managers	- Improve knowledge of water quality managers by obligatory workshops
		- No WWTP - Broken WWTP - Wrong equipment	- Centralized WWTP - Better WWTP
	Unregistered	- No WWTP - No permits, no obligations	
	Common	- Low penalties - Not enough inspectors	- Higher punishments - More inspectors - More law enforcement - Develop a classification system so that customers can see how polluting the industry behind the product is

3 CONCENTRATION DATA AND RIVER SYSTEM

The Citarum River is a heavily polluted river. A lot of different substances are found in the river and on its banks. Some of these substances are produced by nature but are pollutants because of the high concentration in the river. Other substances do not occur in rivers naturally and are therefore pollutants. In order to check whether the substances in the river are pollutants, the maximum permissible concentration (MPC) of substances, set by the government of the Province of West Java, is used, see Appendix A (Perda Jabar No. 39/2000).

In this chapter the severity of the problem is determined with the data from organizations which measure the concentrations in the river. To assure consistency one organization is chosen from which the data is used. At the same time a selection is made of substances which are relevant to review based on land use types, emissions and available data. The average concentration of these substances are used to verify the results of the simulations in SOBEK later on.

Before determining the severity of the impaired water quality, the seasonal discharge per tributary is described. Indonesia has namely a pronounced wet and dry season and a constant discharge for the wet and dry season, respectively, is used in the simulations. Also in this chapter the river system as is in SOBEK is explained.

3.1 Tributaries and selection of modelled rivers

The twenty tributaries of the Citarum River flowing through the Citarum basin are different in length and discharge and are flowing through areas with a variety of land use types. For example, the Citepus flows completely through the city of Bandung, while the river of Ciwidey mainly flows through agricultural areas. This gives different concentrations of substances per tributary.

In Table 2 the length and the average discharge per season of the main tributaries and three points in the main river are shown. The average discharge is determined by summating the discharges measured in the months associated to the specific season and divide this by the amount of measures. The discharges in the wet and dry season are used in the SOBEK model as fixed discharges to calculate the concentrations. The division in wet and dry is made, because of the run off of the different substances of the land which is higher in the wet season and because of the higher concentration in the dry season because of less dilution.

TABLE 2 THE RIVER LENGTH AND AVERAGE DISCHARGE IN THE DRY AND WET SEASON OF TRIBUTARIES IN UPPER CITARUM BASIN. THIS DATA IS BASED ON A DECADE (2002-2012) OF MONTHLY DISCHARGE MEASUREMENTS (EPA, 2015)

River	*River length*	*Dry (April - October)*	*Wet (November - march)*
	km	m^3/s	m^3/s
Citarum - Majalaya	73	2.2	8.9
Citarum - Dayeuh Kolot	73	15.8	53.1
Citarum - Nanjung	73	27.9	313.4
Cirasea	18	1.6	4.7
Citarik	31	1.3	1.9
Cikeruh	25	0.4	1.4
Cipamakolan	10	2.3	3.4
Cidurian	26	1.4	4.5
Cicadas	15	0.8	2.6
Cikapundung	22	2.3	3.4
Cisangkuy	33	6.1	19.9
Cibolerang	4	0.5	0.9
Ciwidey	10	3.7	6.6
Cibeureum	10	0.3	0.4
Cikoneng	15	1.3	4.0
Cisaranten	12	0.6	2.3
Cibeusi	7	0.2	0.6
Cinambo	3	0.2	0.9
Cikapundung Kolot	15	1.6	2.3
Citalugtug	13	4.9	15.9

3.2 Modelled river system

For the modelling process in SOBEK an existing water quantity model, build by Deltares, is used (orange system in Figure 7) and for this study the water quality module D-Waq is enabled. This existing system is not elaborated. All the rivers with a high discharge are in the system and also the rivers from which it is assumed they flow through an industrial area, only urban area or only agricultural areas are modelled (this gives distinctive concentrations). Also, in the calculation of the scenarios the concentration is determined downstream at the measuring station (red star in Figure 7), therefore a much elaborated system is not necessary for this study.

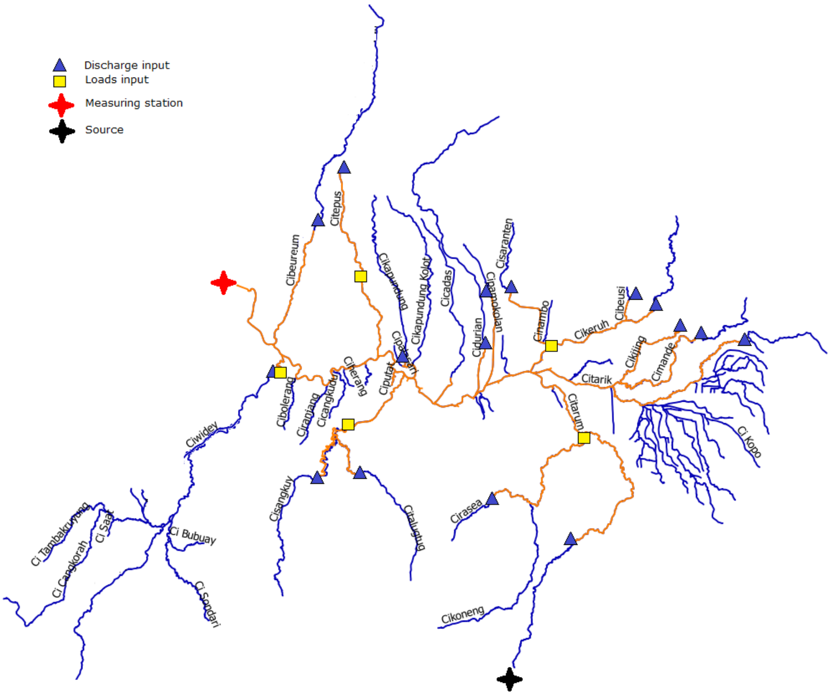


FIGURE 7 MAIN RIVER SYSTEM OF THE UPPER CITARUM BASIN AND IN ORANGE THE RIVER SYSTEM AS MODELLED IN SOBEK

The blue triangles in Figure 7 are the input points for the discharges given in Table 2. These are the start of the rivers in the SOBEK model. The yellow squares are the input points for the loads calculated in Chapter 4. The black star is the source of the Citarum River. This point is corresponding with the most upstream measuring station of PJT-II in Figure 9 (Situ Cisanti). The red star is the measuring station near Nanjung (reservoir) of which the concentrations, calculated by SOBEK with the loads determined in Chapter 4, are measured.

3.3 Monitoring stations and organizations

Different organizations in the Upper Citarum Basin are monitoring the water quality in the Citarum River. Some organizations do more monitoring than others, as shown in Table 3. Also the locations of the measurements deviate per organization. This means that the data per location depends on the measuring organization. Figure 8 shows in time what measurements per organization are available over the period 2010-2012 (period chosen as example) and in Figure 9 the different locations per organization are given.

TABLE 3 MONITORING ORGANIZATIONS, HOW OFTEN AND HOW MANY MEASUREMENTS TAKE PLACE AND IN WHICH TIME PERIOD (VAN GINKEL, 2015)

Organization	*PJT-II*	*EPA West Java*	*PusAir*	*EPA Kab. Bandung*
# locations in Upper Citarum Basin	18	4[1]	4	72 – 75
# measurements/year	12	3 - 5	1 - 2	3
Available data	1993-2014	2001-2014	1990-2013	2008-2013

[1] Before 2011, the West Java EPA used to have 7 monitoring stations. In 2011 three of the sites where removed, due renewed task division after establishment of BBWS, and two other sites were moved to a different location.

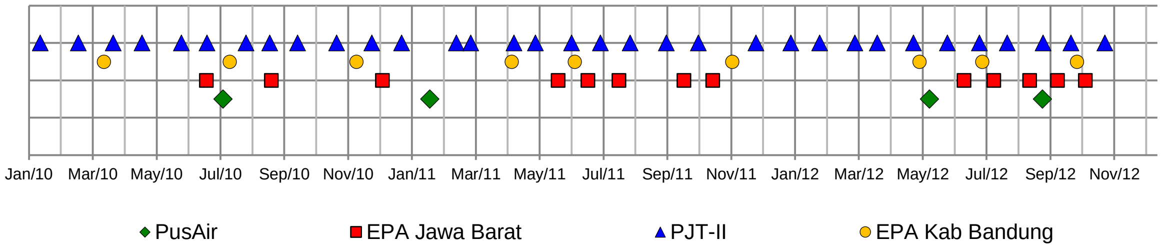


FIGURE 8 MOMENTS OF MEASUREMENT OVER A THREE YEAR PERIOD OF THE DIFFERENT ORGANIZATIONS (VAN GINKEL, 2015)

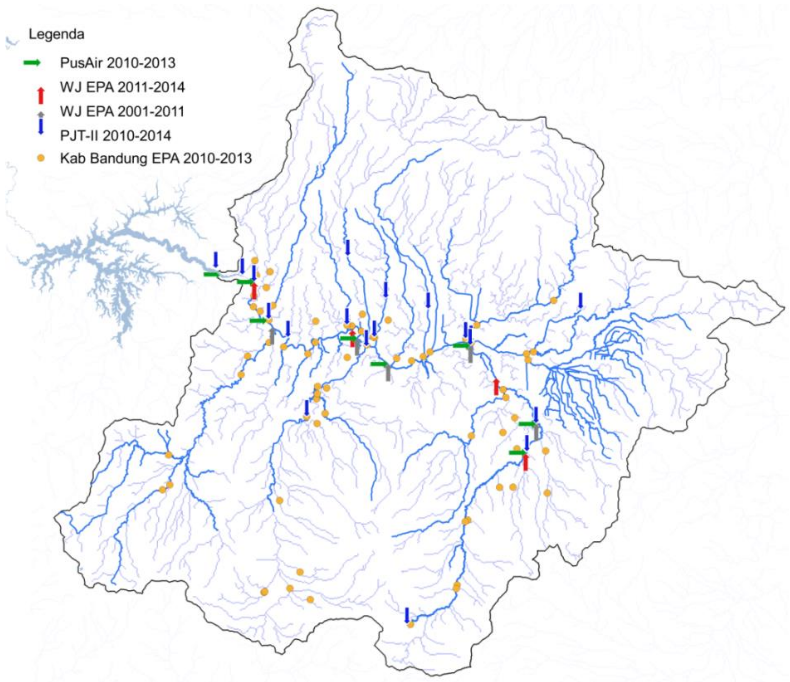


FIGURE 9 WATER QUALITY MONITORING STATIONS OF DIFFERENT ORGANIZATIONS ACROSS THE BASIN (VAN GINKEL, 2015)

For the calculation of the average concentration the data of PJT-II is used. This is based on the availability of data (once every month), the places where the organization measures (18 places in the main system), and consistency in data (choosing one organization). In Figure 10 a schematization of the river system in the Upper Citarum Basin is given with the names and locations of the measuring stations of PJT-II.

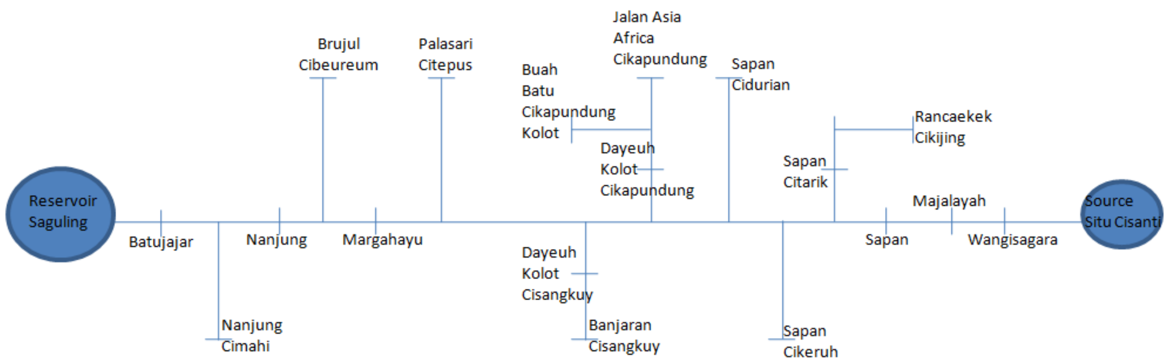


FIGURE 10 SCHEMATISATION OF THE RIVER BASED ON THE MEASUREMENT POINTS OF PJT-II

The period 2010-2014 is chosen, because of the recentness of data. With a fast changing population and growth of the city, also the discharge of loads will change fast. Therefore a certain period is chosen which is long enough to get sufficient data, and recent enough to make it representative for the current situation.

3.4 Substances to model

There are a lot of substances in the river, but not for all substances data is available and modeling all the substances takes a lot of time. Therefore a decision is made to model only a few substances (Table 4) which are representative for the different land use types in the area (see section 1.3); are present in the measured data from PJT-II; and which, at some times, exceed the maximum permissible concentration (Table 5).

Table 4 indicates the contribution of a land use type to the pollution in the river[2]. Some land use types have a larger emission of a certain pollutant than others. The numbers in the table have to be seen relatively to the other land use types. There is of course BOD coming from forests (leaves and branches falling in the river), but is negligible compared to the BOD coming from people.

TABLE 4 CHOSEN SUBSTANCES TO MODEL ACCORDING TO THE LAND USE TYPESS WITH AN ESTIMATION OF THE CONTRIBUTION

	Domestic	*Industry*	*Stockbreeding*	*Crop growing*	*Natural*
BOD	❷	❷	➊	⓪	⓪
COD	❷	❷	➊	⓪	⓪
Nitrate	❷	❷	➊	❷	⓪
Sulphate	➊	❷	⓪	⓪	➊
Zinc	⓪	❷	⓪	⓪	➊
Fecal Coliform	❷	⓪	❷	⓪	⓪

⓪ = not relevant source of pollution; ➊ = small contribution to pollution; ❷ = large contribution to pollution

3.4.1 BOD and COD

Biochemical oxygen demand (BOD) represents the amount of dissolved oxygen needed by aerobic organisms to break down organic material present in the river. This process can be divided into a carbonaceous (CBOD) and a nitrogenous (NBOD) oxygen demand. CBOD is the decay of organic matter into carbon dioxide and water and NBOD is the nitrification of ammonia (e.g.) into nitrate and water (Sullivan, et al., 2010).

Chemical oxygen demand (COD) is less specific, since it represents everything that can chemically be oxidized. There are two ways to determine the COD concentration in the water (in the laboratory). The first is oxidizing the organic matter with potassium chromate and the second is oxidizing it with permanganate. The first is the most efficient, it oxidizes approximately 90% of the organic matter (permanganate: 50%). During the process of oxidizing organic compounds are breaking down into carbon dioxide, water and ammonia. The latter is converted by nitrification into nitrate.

In SOBEK the decay of BOD and COD is modelled as a first-order process. If the water temperature drops below a critical value the decay rate reduces to zero (with an average temperature of 27 °C in the Citarum River, this process never stops) (Deltares, 2015). The decision is made to calculate with the default values of the parameters, because data is missing on the

---

[2] This estimation is based on a discussion session at the University of Twente with the supervisors of this study

process parameters for the Upper Citarum Basin. The only parameter changed is the water temperature (set at 27 °C).

3.4.2 Nitrate

Nitrate is an important nutrient for crops and is often applied as fertilizer, therefore nitrate is an important indicator for agriculture. However, industrial and residential areas can also strongly contribute to high nitrate concentrations (Poor & McDonnell, 2007).

The decay of nitrate is called denitrification. Denitrification is the microbial reduction of nitrate into nitrogen gas, which requires the absence of oxygen. The nitrogen gas can escape to the atmosphere. Eventually the nitrate is removed from the water.

Denitrification is very sensitive to temperature. The higher the water temperature the larger the denitrification (until 60-65 °C (Keeney, 1973)). Below a temperature of 4 °C, the denitrification stops. Besides this only a small number of specialized bacteria are capable of denitrification. (Deltares, 2015). Default values are used for the process parameters which influence the conversion of nitrate.

3.4.3 Sulphate

In de Upper Citarum Basin a volcanic lake is an important source of sulphate to the river (Sriwana et al., 2000), therefore the number 1 in the table at 'natural'. Besides this, sulphate is a waste product in the textile industry.

Table 5 shows that sulphate is not above the maximum permissible concentration. Therefore, sulphate is not in the modelled concentrations in this report and no elaboration on the processes in SOBEK is given here.

3.4.4 Zinc

Zinc is a metal commonly used in the industry in the Upper Citarum Basin (e.g. textile and metal) (Bisschops & Spanjers, 2003).

Heavy metals are not subject to decay. They can form precipitates with other solutes and can be adsorbed to sediments and organic matter. The rate and amount of adsorption depends on the pH, redox-potential and weakly on the water temperature (Deltares, 2015).

3.4.5 Fecal Coliform

Fecal coliform are bacteria which originate in the intestines of warm-blooded animals. The coliforms come in the water with the run off from land, spillages to storm drains from sewages or is discharged directly into the river. The bacteria are often an indicator for the presence of diseases.

The decay of fecal coliform is described by the mortality of the bacteria. The mortality is enhanced by the temperature, salinity and radiation. Available formulations for the mortality of bacteria are mainly empirical (Deltares, 2015).

3.5 Measured concentration of substances

The concentrations of the different substances are changing over space and time. This is due to the seasonality and the location of the different land use types. In a dry season the discharge of water in the river is lower compared to the wet season (Table 2), because there is less water to transport. The expectation is that the concentrations of the different substances in the dry period are therefore higher compared to the wet season.

Figure 11 and 12 show the concentration of BOD and nitrate along the Upper Citarum River on different times according to the measured concentrations by PJT-II. The division in wet and dry season is unfortunately not that clear when looking at the graphs. The concentration in the wet period is more diluted, but also more substances flow from the lands into the river with the run off. This causes that the loads coming in the river is higher compared to the dry season and the concentrations are in same order of magnitude for both seasons.

For BOD the peaks of the different measurements are relatively in line with each other. This means that the BOD is discharged to the river more or less at the same spots (between two measuring stations). This is different for the concentration of nitrate. The graphs show that the peaks and troughs do not line up the same way BOD does, this means that nitrate is emitted at different places.

Both BOD and nitrate are most of the times above the black line indicating the MPC. This means that the concentration is too high at most of the times and places. Besides BOD and nitrate, also the other chosen substances are above the MPC (Table 5). Even at the source of the Citarum River (Situ Cisanti) some substances are already too high.

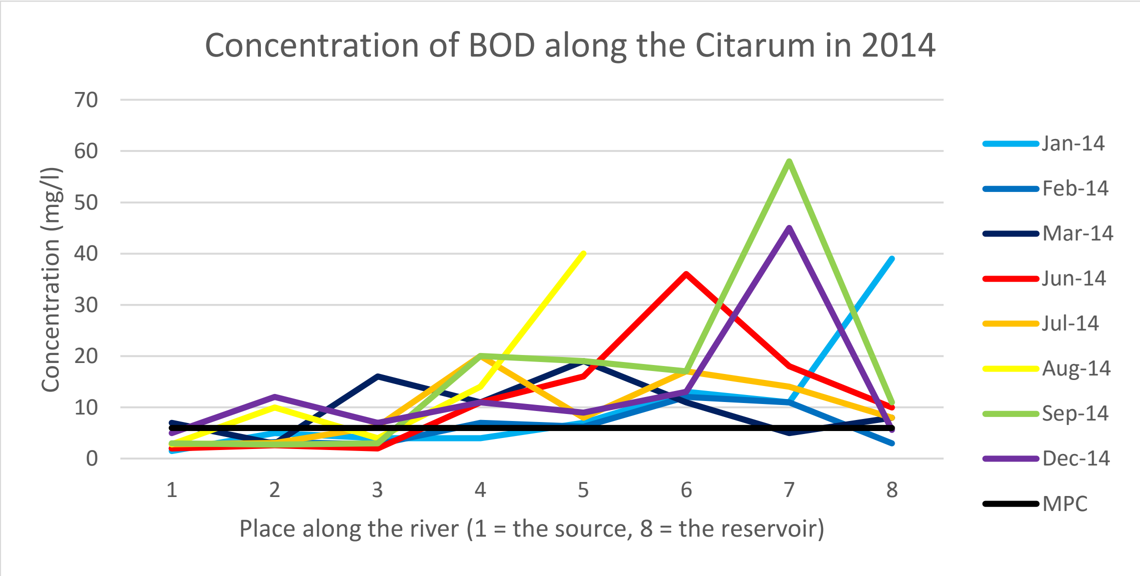


FIGURE 11 CONCENTRATION OF BOD ALONG THE RIVER THE BLACK LINE IS THE MPC ACCORDING TO THE STANDARDS SET BY THE PROVINCIAL GOVERNMENT. THE BLUE COLOURS INDICATE THE WET SEASON AND THE YELLOW, RED AND GREEN ARE IN THE DRY SEASON

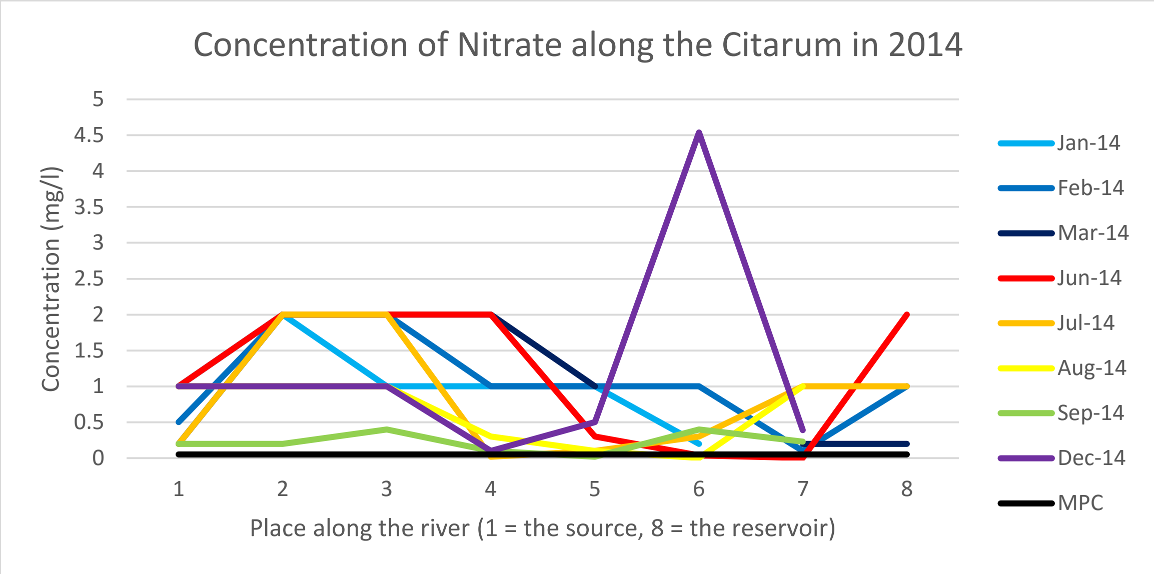


FIGURE 12 CONCENTRATION OF NITRATE ALONG THE RIVER THE BLACK LINE IS THE MPC ACCORDING TO THE STANDARDS SET BY THE PROVINCIAL GOVERNMENT. THE BLUE COLOURS INDICATE THE WET SEASON AND THE YELLOW, RED AND GREEN ARE IN THE DRY SEASON

Table 5 gives the averaged concentrations over a season.[3] This average concentration is determined by dividing the total of the summated concentrations by the amount of measurements. This is a rough way to calculate the average concentration, but because the discharge at the different measurement stations is not known, this way is chosen. Later on in Chapter 4 a comparison is made between the measured concentrations and the calculated concentrations.

[3] The data used in Figure 11 and Figure 12 are measured on one day. The data used in Table 5 is averaged data of multiple data sets over a whole season. This does not mean that when the concentration is too high, this applies for the whole season. It is possible that a certain points, the concentration is within limits.

TABLE 5 AVERAGED CONCENTRATION OF THE CHOSEN SUBSTANCES AT DIFFERENT PLACES IN THE BASIN AND WHETHER THEY ARE ABOVE (RED) THE MPC OR NOT (GREEN)

	BOD (mg/l)		*COD (mg/l)*		*Nitrate (mg/l)*		*Sulphate (mg/l)*		*Zinc (mg/l)*	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Maximum Permissible Concentration	**6**		**10**		**0.05**		**400**		**0.02**	
Outlet Situ Cisanti Citarum	2.9	2.8	7.9	6.8	0.6	0.7	23.9	19.1	0.02	0.01
Wangisagara Citarum	3.6	3.2	12.0	8.2	2.3	1.8	23.5	12.0	0.02	0.02
Majalaya Citarum	3.6	4.5	12.3	13.5	1.8	2.9	21.1	32.3	0.02	0.02
Rancaekek Cikijing	54.6	69.1	169.3	205.8	0.5	0.4	490.6	649.4	0.13	0.10
Sapan Citarik	7.4	19.3	23.0	47.7	1.1	0.9	48.8	91.7	0.02	0.04
Sapan Cikeruh	8.2	20.2	23.7	49.8	1.4	0.8	34.7	60.4	0.02	0.05
Sapan Cidurian	10.0	10.9	33.1	28.8	1.3	3.6	50.2	20.4	0.03	0.01
Sapan Citarum	7.3	24.3	20.9	61.7	1.3	1.4	40.6	74.0	0.08	0.11
Buah Batu Cikapundung Kolot	32.4	25.2	69.7	62.9	0.7	0.3	36.9	21.4	0.08	0.06
Jalan Asia Afrika Cikapundung	10.9	12.4	25.3	32.8	2.9	5.4	17.8	25.0	0.02	0.05
Dayeuh kolot Cikapundung	9.9	14.9	23.9	36.6	2.5	2.4	18.7	20.9	0.04	0.02
Banjaran Cisangkuy	7.7	14.9	21.1	25.9	2.1	1.7	16.1	16.0	0.02	0.07
Dayeuh Kolot Cisangkuy	7.5	13.5	17.6	41.1	1.5	0.8	16.3	29.0	0.05	0.01
Palasari Citepus	33.4	27.7	87.6	69.7	0.7	0.3	44.2	37.2	0.16	0.05
Margahayu Citarum	8.1	18.8	24.5	38.0	1.8	2.8	34.6	51.6	0.06	0.05
Brujul Cibeureum	66.0	52.7	167.6	147.8	0.6	0.5	167.4	164.3	0.14	0.07
Nanjung Citarum	8.4	17.2	24.3	43.2	1.4	1.7	40.1	56.5	0.05	0.04
Nanjung Cimahi	37.9	50.2	105.3	143.8	0.9	18.7	135.2	240.6	0.13	0.19
Batujajar Citarum	10.5	21.8	27.9	47.3	1.1	1.4	48.4	51.7	0.04	0.05
Inlet PLTA Saguling Citarum	7.5	6.2	30.0	18.2	0.3	1.7	44.3	30.5	0.02	0.01

4 EMISSION DETERMINATION

In this chapter the methodology on how to estimate the loads, which are used as input for the model, is described. This is necessary because the measurement data (section 3.5) gives no clear answer from which land use type a particular substance originates and how much is lost by natural processes.

Per land use type a method is conceived to calculate the loads for the six substances used. The loads are determined per sub river basins for the land use types: domestic, industry, animal husbandry and crop growing. The land use type 'natural' is not taken into account any further, because of the lack of data.

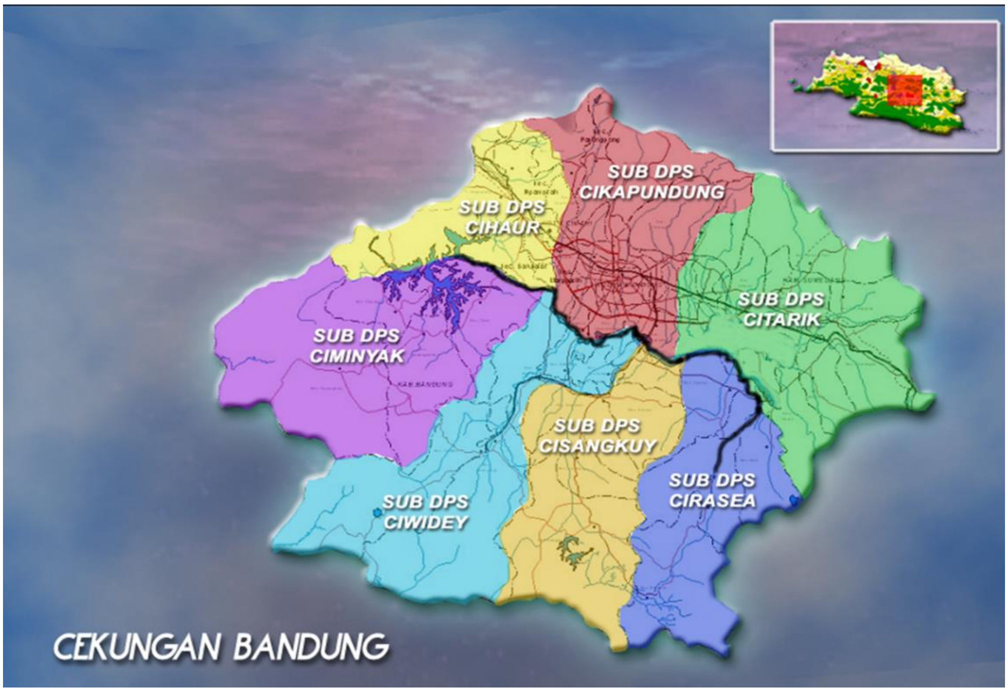


FIGURE 13 BASIN DIVIDED INTO FIVE SUB BASINS (CIMINYAK AND CHAUR ARE NOT INCLUDED) FOR WHICH THE EMISSION DATA IS CALCULATED (BPLHD PROVINCE OF WEST JAVA, 2001)

4.1 Emission from crops

In this section the emission from agriculture is estimated. The land use data shows that most of the land is used for crop growing activities (Figure 3). These cover approximately 45 percent of the total land use in the Upper Citarum Basin. Climatic conditions in this area are favorable for growing vegetables, rice and plantations (tea, fruit trees). In accordance with the land use, approximately 75 percent of the households in the basin are involved in the agricultural sector.

Most developing countries have little or no emission data. The limited data available is used to get the best feasible estimate for emissions in the Upper Citarum Basin. Agricultural emission is heavily affected by the surface area, type of crops, growing time of the crops (including harvesting) and the run off. The surface area is important, because the larger the fields, the higher the loads. The type of crop is important because of the waste it produces. Some crops grow on big plants with a lot of wasted materials, and some crops are used completely. The growing time is used to calculate the emission per hour, because some crops have short growing periods (90 days), but have a large amount of emission (e.g. water spinach). The data available contains only values for BOD, nitrate and sulphate, therefore the other substances are not taken into account in this section.

The next formula is used to calculate the emissions from agriculture:

$$L_{crop} = \sum \frac{E_{crop,i} \times A}{T} \times \alpha \tag{1}$$

With:

- L_{crop} [kg/h] is the total emission of a substance from crops to the river
- $E_{crop,i}$ [g/ha/growing season] is the average crop emission[4] of a certain crop type (i) per growing season
- T [h] is the length of the growing season in hours from planting to harvesting
- A [ha] is the total surface area on which a certain crop is grown in a sub basin
- α [-] is the run off coefficient and is the percentage of the total amount of substance which flows into the river

TABLE 6 CROP CHARACTERISTICS OF A FEW CROPS WHICH GROW IN THE UPPER CITARUM BASIN. AN ELABORATED LIST PER AREA IS ADDED IN APPENDIX C.1 (ISKANDAR, 2013)

Crop	*Area*	*Length of growing season*	*Average emission BOD*	*Average emission Nitrate*	*Average emission Sulphate*
	ha	h	g/ha/growing season	g/ha/ growing season	g/ha/ growing season
Rice	118,740	2880	225	20	10
Corn	9,127	2400	125	10	5
Tomato	450,908	1560	125	10	5
Banana	93,755	2160	32.5	3	1.5
Coffee	5,482	5760	32.5	1.5	1.5
Tea	13,631	336	32.5	1.5	1.5

The emissions given in this table are emissions to the land. This data is retrieved from Iskandar (senior water quality researcher at PusAir, an institute on water resources) who determined this values by combining literature on this topic, verification by field work and conducting interviews with stakeholders on application of fertilizers and pesticides.

Remarkable is that the values found are specific numbers and not ranges. This is strange because, the area is not constant over time but deviates; the plants from the same crop type have different emissions; and the growing season is not per plant the same. All this gives that the total emissions are within a certain range, unfortunately the dimensions of this range cannot be checked. For this

[4] This is the total emission to the field during the growing and harvesting of the crop. The emission comes from the materials of the plants which have fallen to the ground to rot. This leaves and branches contain also residue of applied fertilizers and pesticides.

research, however, the average emissions determined in this source will be used, because these values are specific for the Upper Citarum Basin and no other sources are found with such data.

For the run off coefficient literature is used (Berenzen et al., 2005; Mcdowell et al., 2001; Sonzogni et al., 1980; Willis, 1983). These sources have determined the run off in countries around the world, but mainly in more developed countries and countries situated in higher latitudes. This means a more moderate climate and not high wash loads from the lands. Therefore the highest number from the range (Table 7) is used to calculate the emission in Indonesia.

TABLE 7 RUN OFF COEFFICIENT IN DIFFERENT SEASONS

Season		
Dry	Transition	Wet
0.1% - < 1%	1% - < 2%	2% - 3.5%

Based on the formula and the coefficients of Table 6[5] and Table 7 the loads emitted to the river can be calculated (Table 8). The table shows high values in the Citarik sub basin, compared to the other basins, these can be explained by the size of the crop growing in this area. The Citarik sub basin has the most crop growing activities (Appendix C).

TABLE 8 LOADS EMITTED TO THE RIVER DURING THE WET AND DRY SEASON

	BOD (kg/h)		*Nitrate (kg/h)*		*Sulphate (kg/h)*	
Sub basin	Wet	Dry	Wet	Dry	Wet	Dry
Cikapundung	0.2	0.06	0.02	0.006	0.01	0.003
Cirasea	0.2	0.05	0.01	0.004	0.007	0.002
Cisangkuy	0.2	0.04	0.01	0.004	0.007	0.002
Citarik	9.5	2.7	0.8	0.2	0.4	0.1
Ciwidey	0.04	0.01	0.004	0.001	0.002	0.001

4.2 Livestock

15 percent of the households in the agricultural sector have some sort of livestock activities (Parikesit, et al., 2005). The livestock is kept in barns or can walk freely on the lands. Waste from the animals is not treated and disposed to the lands or directly into the river (section 2.2). In 2013, the total emission from stockbreeding activities was estimated at 1800 ton/day (West Java EPA, 2013).

The total emission to the river from livestock activities depends on the type of animal, the number animals and the run off. A chicken has less excrements compared to a cow, but a lot of chickens can still cause a lot of pollution to the river. The run off coefficient is applied on all animals, because the assumption is made that the majority of emission from animals comes on the land (section 2.2). The animals in barns are assumed only a small portion.

[5] The values in Table 6 are for the whole basin. The values per sub basin are given in appendix C, because these tables are too big to present here

The emission for stockbreeding per day is calculated by multiplying the emitted excreta with the amount of animals and with a run off coefficient:

$$L_{Stockbreeding} = \sum E_{Stockbreeding,j} \times N \times \alpha \quad (2)$$

With:

- $L_{Stockbreeding}$ [kg/h] is the total emission to the river from stockbreeding activities
- $E_{Stockbreeding,j}$ $[\frac{kg}{animal.day}]$ is the emission of a certain type of animal (j) per day
- N [-] is the number of a certain type of animals in a certain area
- α is the run off coefficient[6]

To determine the emission from animals to the river, the number of animals is needed, which deviates per sub basin (Table 9). The data used is from the statistical office of Indonesia. The numbers are rounded to thousands, because the data found are the counted animals on a certain day and the number of animals changes every day.

TABLE 9 NUMBER OF ANIMALS PRESENT IN THE SUBCATCHMENTS (STATISTICAL OFFICE INDONESIA, 2015)

Animals x1000 (-)	*Cikapundung*	*Cirasea*	*Cisangkuy*	*Citarik*	*Ciwidey*	*Total*
Dairy Cows	28	6.1	16.8	5.6	4.4	60.9
Beef Cows	18.2	2.4	1.5	11.2	1.2	34.5
Buffalo	2.6	1.7	0.6	1.5	0.3	6.7
Horse	32	0.3	0.2	0.5	0.2	4.4
Goat	27	7.8	1.8	11.2	2.7	50.4
Sheep	293	167	54.1	135	17.3	666
Free-running chicken	1,215	373	43	244	48	1924
Laying hens	115.9	164	1.3	52.7	0.8	334
Broiler chicken	1,367	9,148	6361	5392	10,531	45,103
Ducks	254	226	95.8	133	24.9	734

The emission per animal per day (Table 10) is necessary to calculate the total emission per animal type. The same source as in section 4.1 is used for the emission data (Iskandar, 2013) and also here the remark can be made that the emission data are in specific numbers and not within a range. Have emission data within a range can give an indication on how the total emission can fluctuate, now this is not the case.

[6] A run off coefficient is added for all the emissions from animals. It causes an underestimation of the real emission to the river, because there are also animals living in barns. Missing data on a division between animals in barns and on the lands is the cause that for all animals a run off coefficient is applied. This run off coefficient is the same as used in the calculation for the run off from crops

TABLE 10 EMISSION PER SUBSTANCES PER ANIMAL PER DAY (ISKANDAR, 2013) AN ELABORATED LIST IN APPENDIX C.2.

(kg/animal/ day)	*COD*	*BOD*	*Nitrate*	*Sulphate*	*Fecal Coliform*
Dairy Cows	0.3	0.087	0.03	0.003	2.9
Beef Cows	0.3	0.1	0.03	0.007	3.2
Buffalo	0.3	0.01	0.06	0.004	4.4
Horse	0.2	0.06	0.01	0.002	2.0
Goat	0.6	0.02	0.03	0.0007	1.0
Sheep	0.08	0.02	0.01	0.001	0.9
Free-running chicken	0.002	0.001	0.0003	0.0001	0.012
Laying hens	0.007	0.001	0.0005	0.0002	0.01
Broiler chicken	0.005	0.002	0.0004	0.0001	0.01
Duck	0.005	0.001	0.0004	0.0002	0.14

The runoff coefficient is the same as used in section 4.1 (Table 7) and together with the loads per animal and the total amount of animals, now the loads per sub catchment into the river can be determined (Table 11).

TABLE 11 LOADS EMITTED INTO THE RIVER DURING THE WET AND DRY SEASON

(kg/h)	*COD*		*BOD*		*Nitrates*		*Sulphate*		*Fecal Coliform*	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Cikapundung	172.6	49.3	51.6	14.7	17.4	5.0	3.5	1.0	950.1	271.4
Cirasea	101.2	28.9	29.6	8.5	9.8	2.8	2.1	0.6	485.4	138.7
Cisangkuy	65.1	18.6	19.2	5.5	5.9	1.7	1.3	0.4	285.0	81.4
Citarik	69.6	19.9	20.6	5.9	7.1	2.0	1.4	0.4	399.2	114.1
Ciwidey	88.5	25.3	25.7	7.3	7.5	2.1	1.9	0.5	242.3	69.2

The values of emitted loads are the highest in the Cikapundung basin. This can be explained by looking at the number of animals per basin. Compared to the other basins, in this basin the most animals live. Except for broiler chickens. These animals are occurring more in the other basins, but because their emission is (per animal) only one percent of the emission of cows, the difference in numbers between the basin should, in this case, be very large to make a notable difference (hundred times bigger).

4.3 Domestic waste

It is estimated that in the Upper Citarum Basin 75 percent of the people in urban areas and 65 percent of the people in rural areas have access to some sort of basic sanitation facilities (septic tank, sewage system). Of this people with access to a sort of sanitation, 40 respectively 20 percent of the urban and rural population have septic tanks to store their waste water (Almy, 2008) (see Table 12). The people without sanitation facilities defecate on the land or directly into the river.

TABLE 12 ESTIMATION OF THE AMOUNT OF PEOPLE WITH ACCESS TO SANITATION

	Inhabitants	*Access sanitation*		*Septic tank*		*No sanitation*
	#people	*%*	*#people*	*%*	*#people*	*#people*
Bandung	2,500,000	75	1,875,000	40	750,000	625,000
Cimahi	500,000	75	375,000	40	150,000	125,000
Rest	5,000,000	65	3,250,000	20	650,000	1,750,000

The determination of the potential loads from households is based on the number of people living in a certain area and the location of this area relative to the river. More people will lead to more waste water discharged to the river. The location of the area is important because of the runoff. The further away from the river, the less waste water will reach the river (groundwater is not taken into account). The run off coefficient is determined by dividing the area into relative distances from the river and each area is assigned a factor which is multiplied with the discharge per person. All this is multiplied by the amount of pollutant a person emits per hour. The total emission from domestic to the river is estimated by:

$$L_{Domestic\ waste} = \sum E_{person,j} \times N \times \gamma \times \beta \quad (3)$$

With:

- $L_{Domestic\ waste}$ [kg/h] is the total emission to the river from domestic waste
- E_{person} [mg/h] is the emission of a certain substance per person per hour
- N [-] is the number of people living in a certain area
- γ [-] is the distance factor
- β [-] is the urbanization factor

4.3.1 Emission per person

The emission of households mainly consists of black and grey water. The solid waste is not taken into account here because it is not dissolved in water.

Per human around 100 liters of water a day is used and discharged (Büsser, n.d.; Campos & Von Sperling, 1996; Sunarsih et al., 2013). This includes laundry, bathroom (washing) and kitchen sink water (grey water) and water from toilets (black water) (Casanova et al. 2001).

Around 80 percent of the 100 liters consists out of grey water. This is an estimation based on data from industrialized countries where this percentage ranges from 50 to 80 percent (Imhof & Mühlemann, 2005). Data of developing countries is not available. Here 80 percent is chosen because the expectation is that people in Indonesia use relatively less water in their toilets compared to more developed countries.

The assumption is made that this 80 percent is evenly distributed over laundry, bathroom and kitchen. The concentrations of the different substances chosen in section 3.4 in the waste water are shown in Table 13.

TABLE 13 CONCENTRATIONS FOR DOMESTIC DISCHARGE IN MILLIGRAM PER LITER (A: ALMY, 2008; B: ASSESSMENT & QUALITY, 2013; C: IMHOF & MÜHLEMANN, 2005)[7]

	COD (mg/l)	*BOD* (mg/l)	*Nitrate* (mg/l)	*Sulphate* (mg/l)	*Fecal Coliform* (bacteria/l)
Laundry	375[C]	150[C]	0.5[C]	-	-
Bathroom	1000[C]	170	2.5[C]	25	-
Kitchen sink	1000[C]	600[C]	-	-	-
Toilet	610[A, B]	220[A, B]	0[A, B]	20[A, B]	300000[A, B]

In the literature used to determine the concentrations of the different substances in the household waste water, some anomalies are found. The concentrations of COD and BOD in the waste water from bathroom and kitchen sink are very high compared to the waste water from the toilet. For COD the reason is that also the household chemicals like soap and detergent are included. The high levels of BOD are assumed to be caused by the food waste flushed through the sink. The absence of nitrate in the waste water from toilets is because the human body converts nitrate into nitrite before it is emitted in the urine.

This concentration can then be multiplied with the discharge per person to get the loads per person per hour (see Table 14).

TABLE 14 POLLUTANT LOADS PER PERSON PER HOUR

	COD (kg/h)	*BOD (kg/h)*	*Nitrate (kg/h)*	*Sulphate (kg/h)*	*Fecal Coliform (bacteria/h)*
Laundry	0.0004	0.0002	0.000001	-	-
Bathroom	0.001	0.0002	0.000003	0.00003	-
Kitchen sink	0.001	0.0007	-	-	-
Toilet	0.0005	0.0002	-	0.00007	0.25
Total	0.003	0.001	0.000003	0.00005	0.25

4.3.2 Distance factor

The distance factor is a factor which is applied to the emissions and depends on the distance to the river. The further away from the river, more pollutants will infiltrate into the ground and less pollution will reach the river. Besides the distance also the usage of a septic tank causes a decrease in discharge of pollution to the river.

[7] In the paper of Imhof and Mühlemann ranges are found for the different substances from laundry, bathroom and kitchen sink. These ranges are averaged for this study, because for the calculations one value is needed.

TABLE 15 RUN OFF COEFFICIENT AND THE EXTRA COEFFICIENT WHEN A SEPTIC TANK IS PRESENT (ISKANDAR, 2013)

Distance to the river	*Run off coefficient*	*Run off with septic tank*
0-100	1	0.4
100-500	0.85	0.34
500 and further	0.3	0.12

In the urban areas many small rivers and channels are conveying the water to the main river. The runoff ratio factor is set to 1 in this area. In the other areas the ratio is set to 0.85 because the assumption is made that nowhere a tributary of drainage ditch is further away than 500 meters. A septic tank stores the water at the source and is not discharged to the river, but because of a chance of seepage, spillage or overflow, a factor 0.4 is added to the run off. This is on top of the coefficients for the distance to the river (Table 15).

4.3.3 Urbanization factor

The urbanization factor is a correction for the impervious surface. In cities there are more buildings and paved areas compared to rural areas, so there is more run off in cities. The run off in cities is set to 1 as reference and an assumption is made what the relative discharges for sub urban and rural are (Table 16).

TABLE 16 DEGREE OF URBANIZATION AND ASSOCIATED URBANIZATION FACTOR B (ISKANDAR, 2013)

Degree of urbanization	*Urbanization factor*
City	1
Sub Urban	0.812
Rural	0.625

The Upper Citarum Basin is a very populated area. Besides the two cities of Bandung and Cimahi many villages are located in the basin. Therefore the designation of 'Rural' is nowhere applicable. The area where the land use type is labeled settlement (Figure 3), there the factor 1 is applied. The other areas will get the factor for sub urban areas.

4.3.4 Loads

To determine the total loads emitted to the river, first the amount of people per area has to be defined. The people per area are divided over the distance to the river and the way of sanitation (Table 17).

TABLE 17 AMOUNT OF PEOPLE IN THE DIFFERENT SUB BASINS AND HOW FAR FROM THE MAIN RIVER

District		*Between 0-100 meter*			*100 meter and further*		
People x1000	Total people	Total people	septic tank	no sanitation	Total people	septic tank	no sanitation
Cikapundung	3,179	36.7	11.0	9.2	3,142	943	786
Cirasea	722	19.2	5.7	4.8	703	211	176
Cisangkuy	837	12.1	3.6	3.0	825	248	206
Citarik	7,688	144	43.3	36.0	7,543	2,263	1,886
Ciwidey	675	46.7	14.0	11.7	629	189	157

When the loads are multiplied by the number of people in the area, the total amount of pollutant load is found for a certain area. The total loads emitted from domestic activities is given in Table 18.

TABLE 18 LOADS PER AREA IN KILOGRAMS PER HOUR

	COD (kg/h)	*BOD (kg/h)*	*Nitrates (kg/h)*	*Sulphate (kg/h)*	*Fecal Coliform (bacteria/h)*
Cikapundung	3,152	1,207	3.3	51.2	250,500
Cirasea	718	275	0.8	11.7	57,000
Cisangkuy	831	318	0.9	13.5	66,000
Citarik	7,635	2,924	8.1	124	606,400
Ciwidey	677	259	0.7	11	53,750

The Citarik basin has the highest emission of loads from households compared to the other basins. This is because the population in this basin is the highest, plus in this area the number of people without sanitation is the highest.

4.4 Industry

The determination of emissions from the industry is based on discharge permits, issued by the local governments. This permit is needed for industries or other activities to discharge waste water onto the water systems in Indonesia. The industries have to monitor the concentration of waste water discharged and report this to the local government each month. The government does random monitoring of the concentration in order to check whether the industries comply with their permits.

To calculate the industrial pollution load, monthly self-monitoring datasets from industries are hard to use, because it does not represent the real discharge (section 2.4.1). For further calculation of the pollution loads from industrial activities, the monitoring results from the government will be used and not the self-monitoring results, even though the dataset from the government is limited and it is taken at a particular point in time. The calculation is done by following the next scheme:

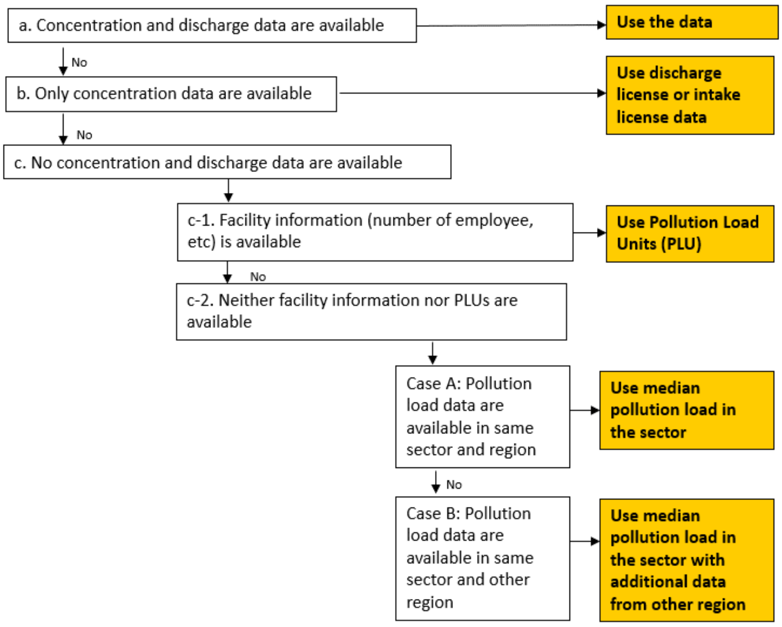


FIGURE 14 STEPS TO CALCULATE THE EMISSIONS FROM INDUSTRIAL ACTIVITIES

a. Concentration and discharge data are available

Category a (Figure 14) are factories which are checked by the government and from which both discharge as well as concentration data is available (Table 19). This data can be easily transferred to loads.

b. Only concentration data available

The second category (b) of data are industries for which only the concentration of the different substances in the waste water is known (checked by the government). In this case the data is complemented with the discharge data which is on the permit of the relevant industry.

c-1. Facility information is available

When both the concentration data as the discharge data is not known, other ways should be used to calculate the loads. The pollution load unit (PLU) is a way of calculating the load based on the amount of people working in the factories, the output of products, or the use of water. It gives a rough estimation of the pollution.

For this research there is not enough data available to calculate the PLU, so this method will not be used to calculate the pollutant loads.

c-2. Neither facility information nor PLU's are known

From around a third of the registered industries, no data is available. They do not have monitoring records, data from permits or the necessary information to calculate the PLU. To determine the loads coming from these industries, the data of the industries where the discharge and concentration data is known is used to calculate a mean load. This value is then used for the industries for which no data is available.

When the emissions are known (in mg/l) it is multiplied by the discharge to get the loads per industry per area.

$$L_{industry} = \sum E_{factory,j} \times N \quad (4)$$

With:

- $L_{industry}$ [kg/h] is the total emission of a substance to the river from industrial activities
- $E_{industry,j}$ [g/h] is the emission per factory per hour for a certain factory (j)
- N is the number of factories with the same industrial activities

4.4.1 Number of industries

In the Upper Citarum Basin there are 383 factories which have a permit to discharge on the river. The majority of these factories are textile factories. From the total of 383 registered factories only 74 are checked by the government and from these both concentration data as discharge capacity is known. From 195 factories only the concentration data is available (Table 19). The government checks not all factories, because of budgetary reasons.

TABLE 19 NUMBER OF REGISTERED INDUSTRIES AND THE NUMBER PER TYPE IN THE UPPER CITARUM BASIN (EPA, 2015) THE PERCENTAGES IN THIS TABLE ARE RELATIVE TO THE TOTAL NUMBER OF REGISTERED FACTORIES OF THAT TYPE OF INDUSTRY.

Type of industry	*No of registered factories*	*No of Checked factories*	*%*	*No of factories of which only concentration data is available*	*%*
Textile	276	54	20	144	52
Pharmacy	19	8	42	5	26
Basic Metal	18	4	22	4	22
Food & Beverages	16	2	13	9	56
Chemical	11	3	27	2	18
Geothermal	8	0	0	8	100
Paint	5	0	0	3	60
Pulp and Paper	4	1	25	2	50
Tea	3	2	67	1	33
Others	23	0	0	17	74
Total	**383**	**74**	**19**	**195**	**51**

So from 269 factories data is available to calculate the emission. From the other 114 factories no data is available.

4.4.2 Measured substances

Not all substances occurring in the river are measured and monitored by the government. For the substances which are modelled in this research (Table 4), the substances in Table 20 are per industry the substances which are monitored and of which data is available. This indicates why sulfate and fecal coliform are not in the further calculations and why nitrate only contributes a relative small portion.

TABLE 20 CHOSEN SUBSTANCES FOR THIS RESEARCH WHICH ARE MONITORED ACCORDING TO THE GOVERNMENT. THE SUBSTANCES WITHOUT A CHECK ARE NOT MEASURED AND MONITORED BY THE GOVERNMENT.

Type	*BOD*	*COD*	*Nitrate*	*Sulfate*	*Fecal coliform*	*Zinc*
Textile	√	√				
Pharmacy	√	√				
Basic Metal						√
Food & Beverages	√	√	√			√
Chemical	√	√				√
Geothermal	√	√				
Paint		√				
Pulp and Paper	√	√				
Tea	√	√				
Others	√	√				

Conclusion registered industry

The methods in the previous sections are used to calculate the loads for the substances chosen for this research. The results are then presented per sub basin.

The results of these calculations are shown in Table 21. It shows the amounts of zinc discharged to the river are very low. The textile industry is in every sub basin the biggest polluter.

TABLE 21 LOADS PER DISTRICT PER TYPE OF INDUSTRY IN KG PER HOUR

(kg/h)		*BOD*	*COD*	*Nitrate*	*Zinc*
Cikapundung	Textile	68.0	187.6	0	0
	Paint	0	0.1	0	0
	leather	0	0	0	0
	Pharmacy	5.2	8.9	0	0
	Paper	0.4	1.6	0	0
	Chemistry	0	0.1	0.03	0.0002
	Metal	0	0	0	0.003
	Food	1.4	3.6	0.14	0.002
	Other	0.6	1.5	0	0
	Total	75.5	203.4	0.2	0.0
Citarik	Textile	56.5	153.0	0	0
	Paint	0	0	0	0
	leather	0	0	0	0
	Pharmacy	0.1	0.1	0	0
	Paper	0.3	1.4	0	0
	Chemistry	0	0.1	0.03	0.0003
	Metal	0	0	0	0.0002
	Food	0.2	0.4	0.02	0.00024
	Other	1.1	3.0	0	0
	Total	58.1	158.0	0.05	0.0008
Cirasea	Textile	62.5	167.1	0	0
	Total	62.5	167.1	0	0
Cisangkuy	Textile	44.7	121.7	0	0
	Geothermal	0.3	0.9	0	0
	Pharmacy	0	0	0	0
	Paper	39.6	80.3	0	0
	Chemistry	0.1	0.6	0.17	0.0015
	Metal	0	0	0	0.00001
	Food	0.4	1.0	0.04	0.00060

	Tea plantation	0.102	0.325	0	0
	Other	13.1	35.8	0	0
	Total	98.3	240.7	0.2	0.0
Ciwidey	Textile	18.2	60.5	0	0
	Chemistry	0	0	0	0.00002
	Tea plantation	0.002	0.004	0	0
	Total	18.2	60.5	0.0	0.0

4.4.3 Unregistered industry

Besides the industries with a permit, there is also a large portion of industry which is not registered (see 2.4.2). The government of West Java province estimates that there are 1500 industries in the Upper Citarum River basin of which only 383 are registered. These unregistered industries are usually small industries, but can have a significant contribution to the pollution into the Citarum River because these industries do not have waste water treatment plants and discharge the water directly onto the water system.

A way of calculating the emission from unregistered industries is described in Appendix E, unfortunately there is not enough data available to calculate the emissions from the unregistered industry. Therefore it is assumed, based on the amount of unregistered factories (1100 versus 400 registered) and the knowledge that the unregistered industries are small factories, that the emissions calculated for registered industries are doubled to get the amount of emission for unregistered industry. In total the emission from the registered industries is tripled to get from all the total emissions from the all industries (Table 22).

TABLE 22 LOADS FROM REGISTERED AND UNREGISTERED INDSUTRIES COMBINED (IN KILOGRAMS PER HOUR)

(kg/h)	*BOD*	*COD*	*Nitrate*	*Fecal Coliform*	*Sulfate*	*Zinc*
Cikapundung	226	610	0.5	0	0	0.015
Citarik	174	474	0.2	0	0	0.002
Cirasea	187	501	0.0	0	0	0
Cisangkuy	295	722	0.6	0	0	0.006
Ciwidey	54	181	0.01	0	0	0.00005

4.5 Overview of loads

For the four land use types the loads of six substances are calculated in the previous section. These loads can be added together to get a load per substance which enters the river per catchment.

TABLE 23 COMBINED LOADS FROM ALL THE LAND USE TYPES AND SUBSTANCES FOR THE WET SEASON

(kg/h)	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	3936	1486	21.3	55	251398	0.01
Cirasea	1320	492	10.5	14	57500	0
Cisangkuy	1618	633	7.5	14.8	66301	0.006
Citarik	8178	3128	16.1	126	606845	0.002
Ciwidey	947	340	8.2	12.9	53992	5E-05

TABLE 24 COMBINED LOADS FROM ALL THE LAND USE TYPES AND SUBSTANCES FOR THE DRY SEASON

(kg/h)	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	3812	1449	8.8	52.2	250719	0.01
Cirasea	1248	471	3.6	12.3	57153	0
Cisangkuy	1572	619	3.2	13.9	66098	0.006
Citarik	8128	3107	11	125	606560	0.002
Ciwidey	883	321	2.9	11.5	53819	5E-05

It depends per sub basin how much effect a sub basin has on water quality. Each sub basin has a different distribution of land use types leading to different loads (Figure 15 and 17[8]). For example, the emission from zinc only comes from industry so according to the pie charts of Figure 15 it can be said that factories are concentrated in the Cikapundung area. The basin with overall the biggest contribution is the Citarik basin. This is because this basin has the largest population of people and animals.

Table 23 and 24 show the total emission coming from the different sub basins in the wet and dry season. The difference between wet and dry is for BOD, COD, sulphate, fecal coliform and zinc not big. While there is almost no run off from the lands in the dry season and thus less substances flowing to the river. The explanation is that for COD, BOD, sulphate and fecal coliform, the emission from households is the biggest and for zinc comes from industry. In the beginning the assumption is made that the emission from these two land use types are constant over both season, therefore there is not a significant difference between wet and dry. For nitrate there is a notable difference. This is because nitrate mainly comes from livestock activities (stockbreeding) and the loads form this land use type is depending on run off and thus changes a lot per season.

The pie charts of Figure 18 and 19 give an indication on how much each land use type is contributing to the pollution problem. Domestic is for almost all substances the largest contributor, this can be explained by the large number of people living in the area. Based on the estimations, agriculture has the smallest contribution to the total loads.

Pie charts, about what land use type is dominant per substance, are added in Appendix F: Results emission estimation.

[8] These pie charts are based on the values at the downstream point, near the Saguling reservoir. This can be the reason that the Cirasea area has not a big contribution because the degradation processes have had some time to work

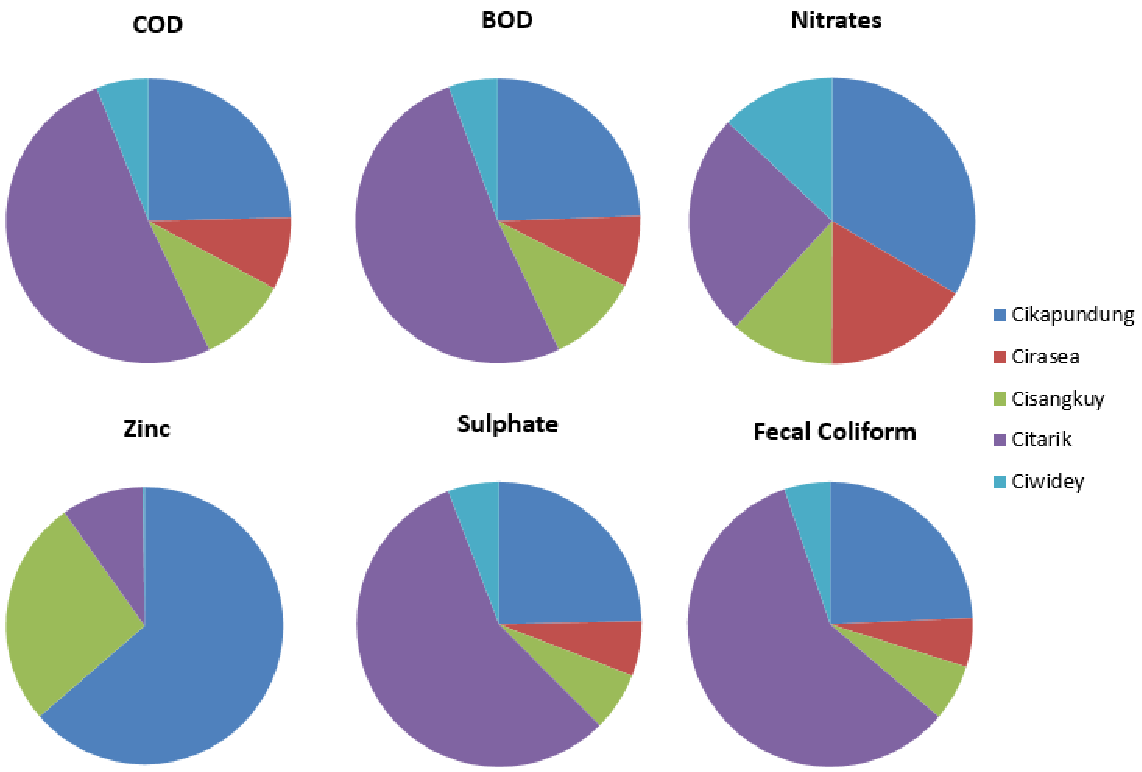


FIGURE 15 CONTRIBUTION OF SUBBASINS TO THE DIFFERENT SUBSTANCES IN THE WET SEASON

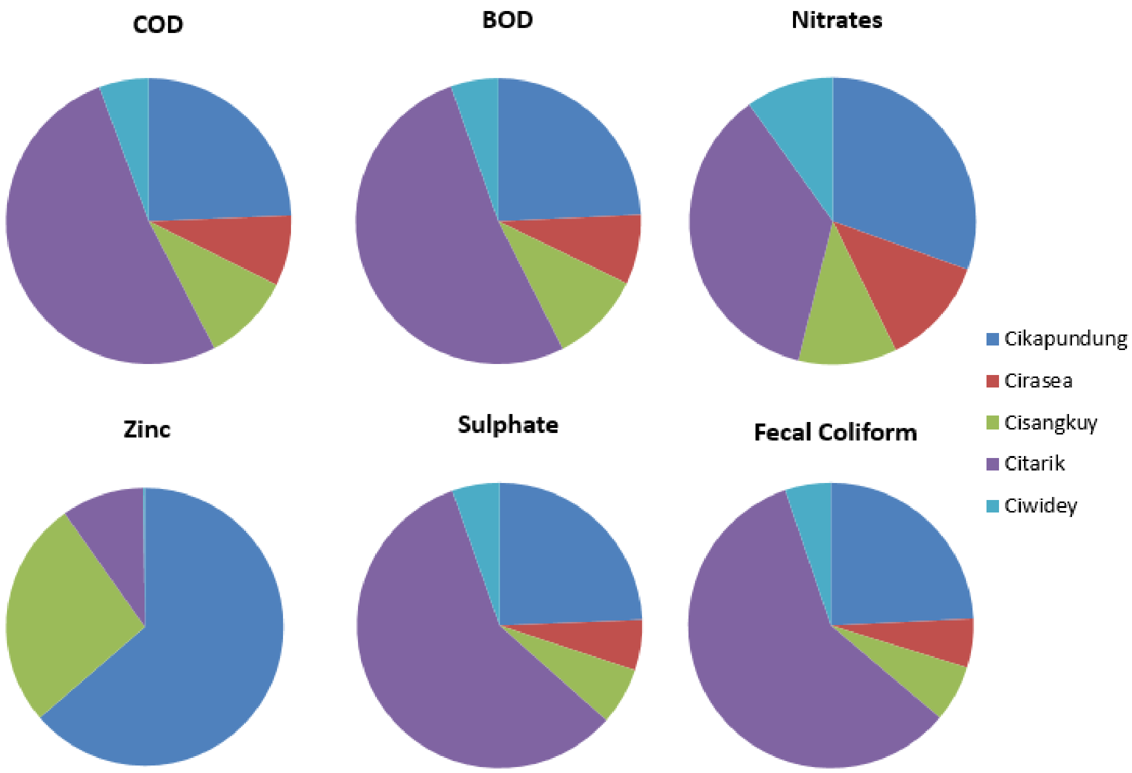
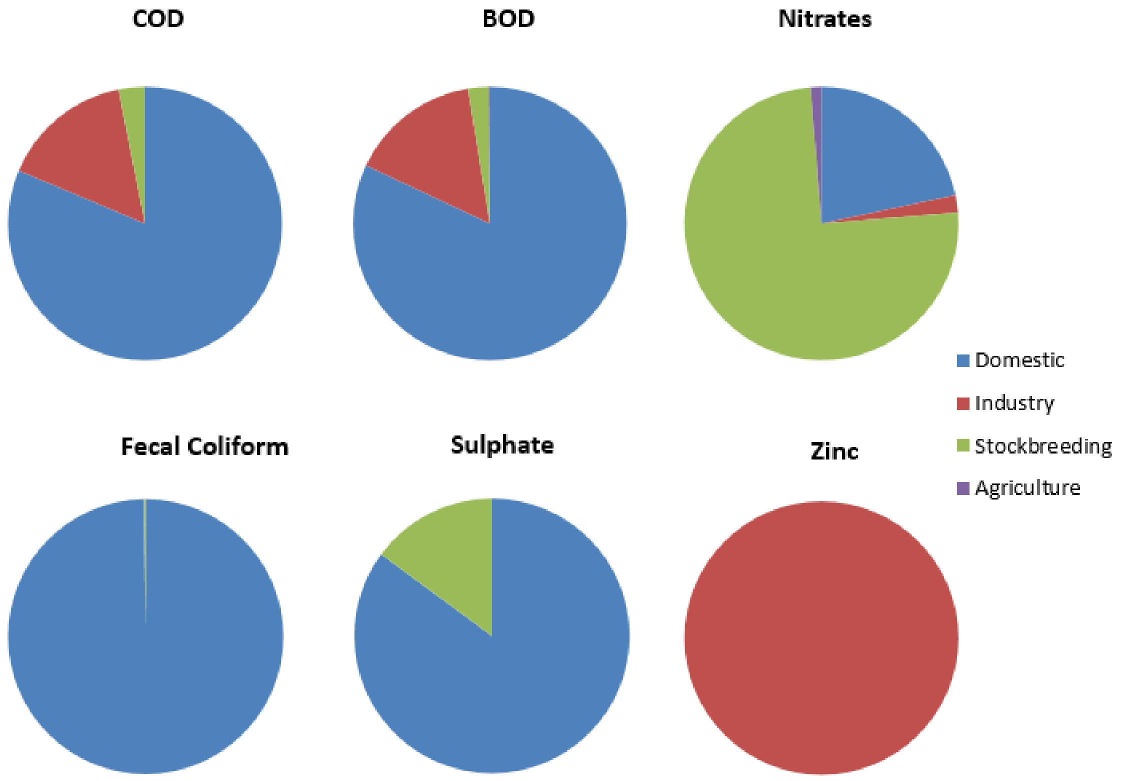


FIGURE 16 CONTRIBUTION OF SUBBASINS TO THE DIFFERENT SUBSTANCES IN THE DRY SEASON



FIGUUR 17 CONTRIBUTION OF THE DIFFERENT LAND USE TYPES TO THE CHOSEN SUBSTANCES FOR THE WHOLE CITARUM BASIN IN THE WET SEASON

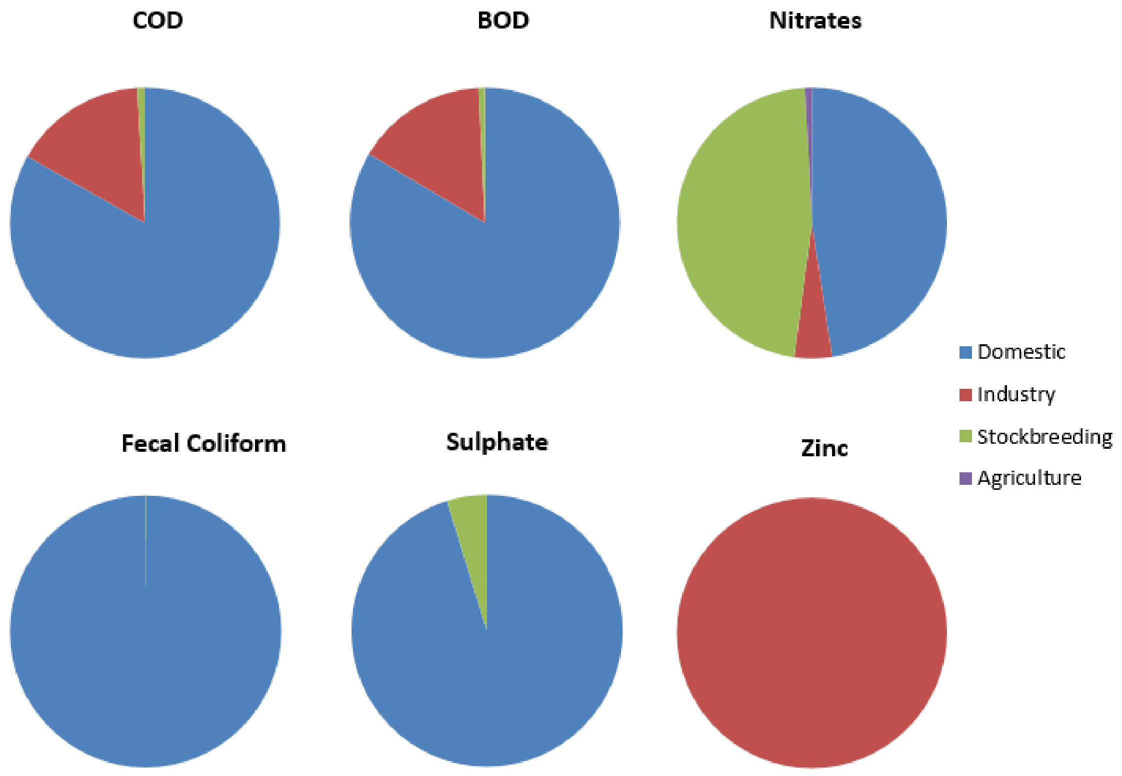


FIGURE 18 CONTRIBUTION OF THE DIFFERENT LAND USE TYPES TO THE CHOSEN SUBSTANCES FOR THE WHOLE CITARUM BASIN IN THE DRY SEASON

4.6 Calculated concentrations by SOBEK

The calculated loads are used as input for the SOBEK model to simulate the concentrations at a downstream point (red star in figure 19). Per sub basin one emission point is selected where the loads of the whole basin are entering the river. These points are placed in the middle (length wise) of the river or at a confluence of two rivers (yellow squares in figure 19). The further downstream the load input points are placed, the less time the processes have to work on the substances and this leads to an overestimation. The further upstream the more time the processes have, so this gives an underestimation of the concentration. Placing the input points roughly in the middle will balance this. For the loads from the Ciwidey basin (Figure 19) it is not possible to place in input in the middle of the river, because the modelled Ciwidey River is very small. Therefore the concentration will be an overestimation. The concentrations are calculated for the wet and the dry season separately with the loads given in Table 23 and Table 24 (Figures 20-23), a constant discharge (Table 2) and stationary conditions (temperature, wind, radiation, and all constant).

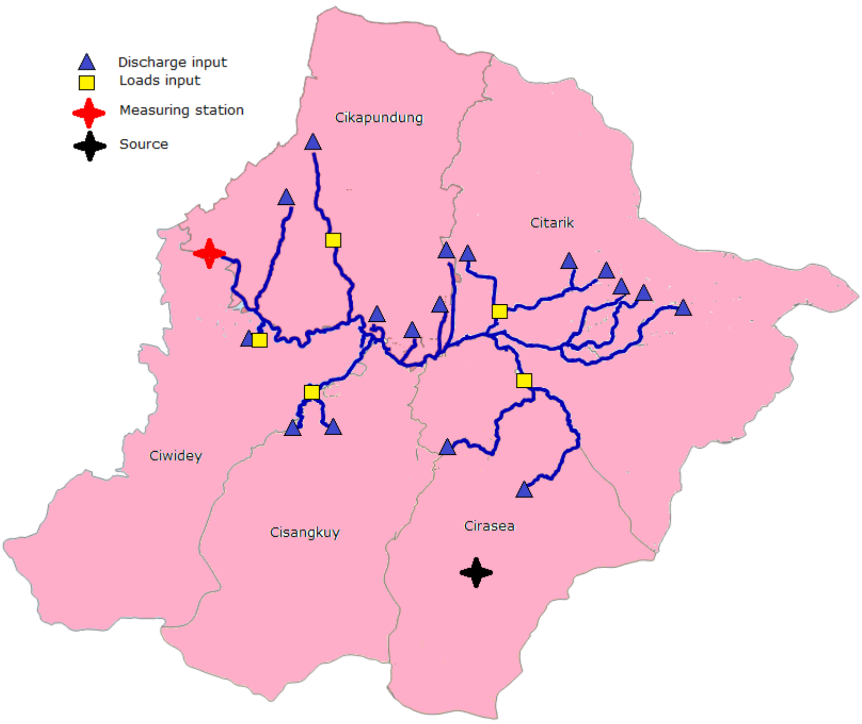


FIGURE 19 UPPER CITARUM BASIN WITH THE RIVER SYSTEM AS IT IS IMPLEMENTED IN SOBEK, WITH BLUE TRIANGLES THE DISCHARGE INPUT FROM TABLE 2, THE YELLOW SQUARES IS WIHERE THE LOADS ARE ADDED AS GIVEN IN TABLE 24 AND 25, AND THE RED STAR IS THE MEASURING POINT FOR WHICH ALSO THE OUTPUT OF THE MODEL IS GENERATED

The difference between the concentrations in the wet and dry season in the figures below is explained by the difference in discharge, where the loads stays roughly the same over the year (for industry and domestic). A higher discharge leads to more dilution and therefore a lower concentration. Also the time it takes before the concentration reaches its equilibrium is different and is depending on the discharge and the processes.

The Upper Citarum River is only 90 kilometers long, so the residence time of the water is also limited (19 hours). This is shown in the graphs by the offset in the beginning, caused by an imposed initial depth (0.5 meter) which does not correspond to the water depth caused by the applied discharges. However, this is not the time it takes for the concentration to reach an equilibrium. For the wet season the equilibrium is reached around the 250 hours and for the dry season it takes 650 hours.

The time it takes before the concentrations reach an equilibrium has to do with the processes in SOBEK (as described in section 3.4), these processes take time. There is also an exchange with the sediment (and with air) which influences the time to reach an equilibrium. When the soil (and air) is saturated an equilibrium can be reached. The difference in time before reaching equilibrium in the wet and dry season has to do with the concentration. The higher the concentration, the longer it takes before an equilibrium is established between water, soil and air.

The graphs below also show that BOD is degraded. The separate runs for each land use type do not add up to the concentration of the total emission. This has to do with the first-order decay process (the higher the concentration, the faster the decay)[9].

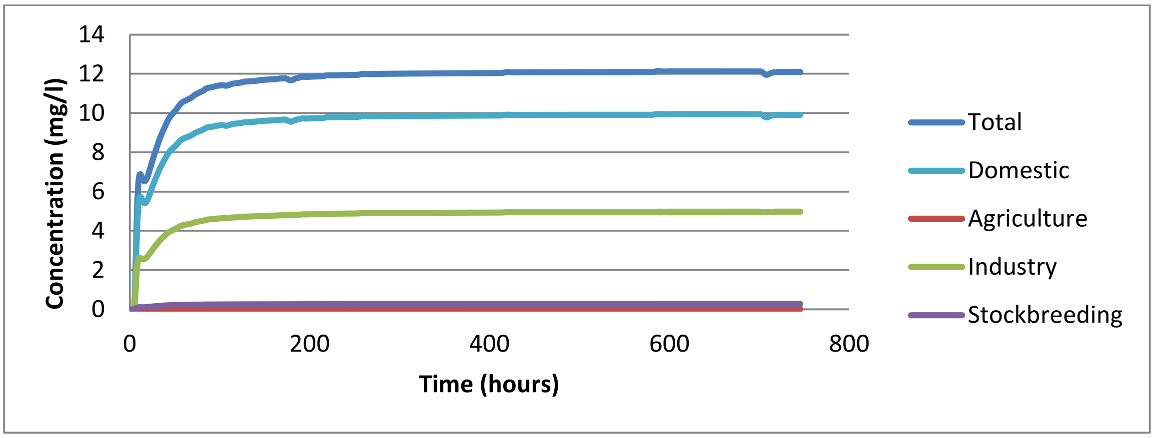


FIGURE 20 CONCENTRATION OF BOD IN THE WET SEASON FOR THE DIFFERENT LAND USE TYPES SEPARATELY AND COMBINED (TOTAL) AT DOWNSTREAM POINT

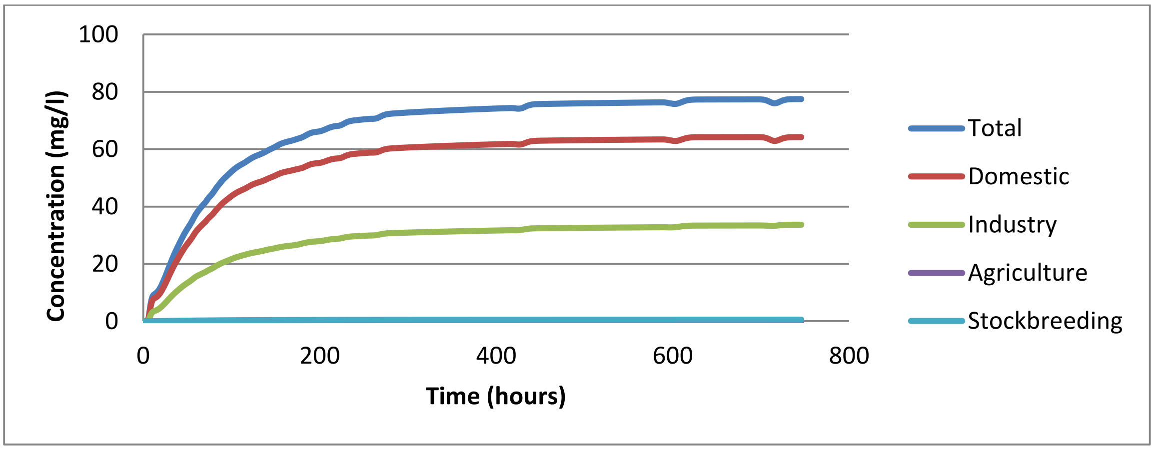


FIGURE 21 CONCENTRATION OF BOD IN THE DRY SEASON FOR THE DIFFERENT LAND USE TYPES SEPARATELY AND COMBINED (TOTAL) AT DOWNSTREAM POINT

[9] Example of BOD in the wet season Domestic (≈10) + Industry (≈5) + Stockbreeding (≈0) + Agriculture (≈0) ≠ Total (≈12)

According to the model nitrate is a more conservative substance compared to BOD. The separated land use types are adding up to the line of the combined land use types[10].

The exchange with the soil (adsorption) is only the case with BOD, COD, and zinc. Nitrate is not adsorbed by the soil. The long time to reach equilibrium is therefore only dependable on the decay and generation. It also takes longer for nitrate to reach an equilibrium (around 400 and 720 for the wet and dry season). This has to do with the generation of nitrate from BOD and COD.

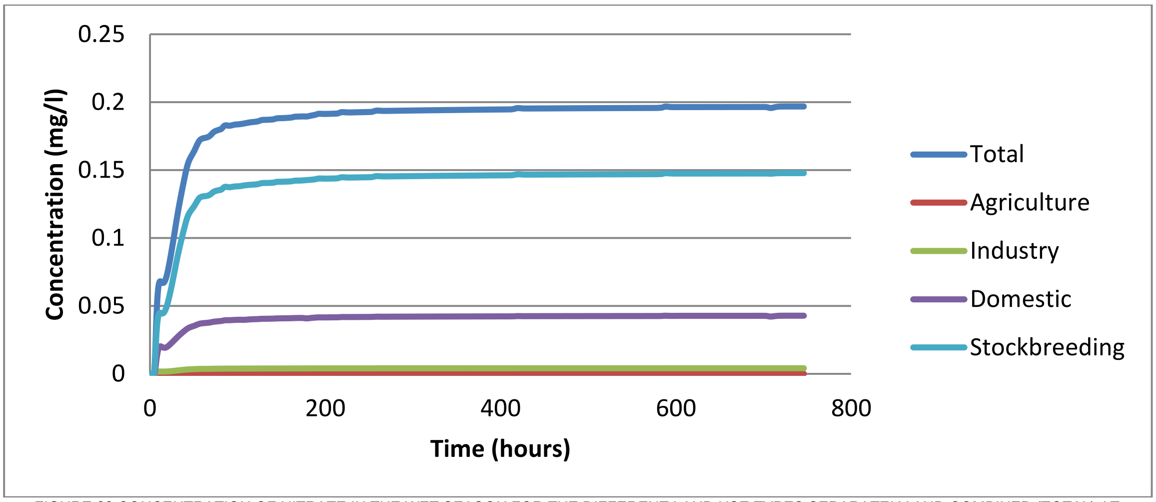


FIGURE 22 CONCENTRATION OF NITRATE IN THE WET SEASON FOR THE DIFFERENT LAND USE TYPES SEPARATELY AND COMBINED (TOTAL) AT DOWNSTREAM POINT

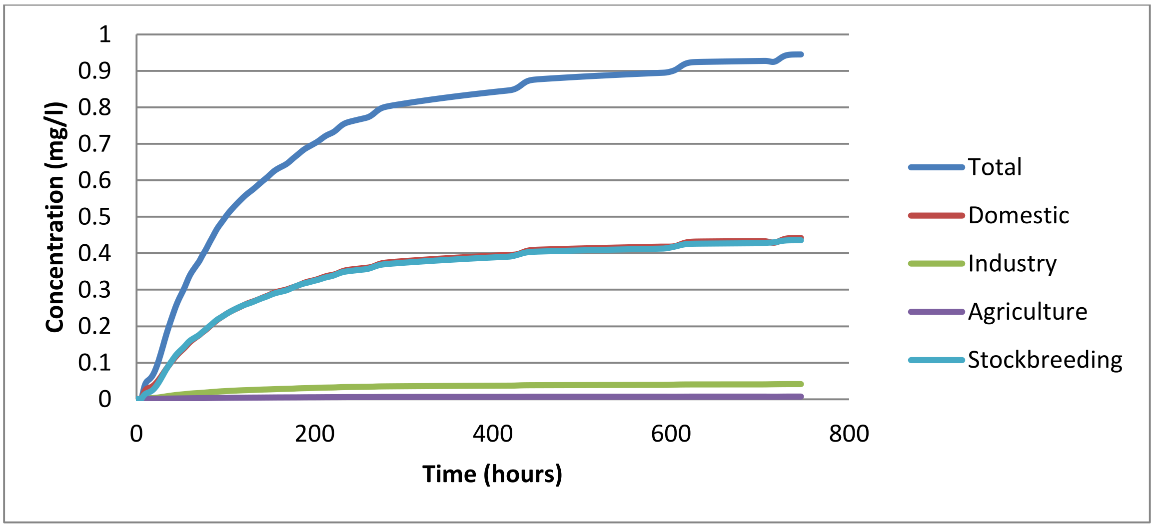


FIGURE 23 CONCENTRATION OF NITRATE IN THE DRY SEASON FOR THE DIFFERENT LAND USE TYPES SEPARATELY AND COMBINED (TOTAL) AT DOWNSTREAM POINT

[10] Example with concentration of nitrate in the wet season: Stockbreeding (≈0.15) + Domestic (≈0.05) + Industry (≈0) + Agriculture (≈0) ≈ Total (≈0.2).

4.7 Comparison between measured and calculated concentrations

Each of the five sub basin has, in the model, one emission point to the river for all the rivers which are situated within that sub basin (Figure 19), because of this it is not possible to get a reliable concentration of the different substances at any given point in the river. The most reliable point for which a comparison can be made between measured and simulated values is a point near the reservoir (Nanjung). At this point all the rivers have merged and the processes have had time to work. Therefore the point Batujajar Citarum (red star in Figure 19) is chosen, because this is the measuring station of PJT-II which is located closest to the inlet of the reservoir.

In Table 25 the results of the SOBEK runs of the previous paragraph in concentrations are added. Besides this the concentrations of the substances when they are treated like conservative substances to show the quantitative impact of the different processes are added. These values are compared to the measured values by PJT-II at Batujajar (see Table 5). The conservative concentrations are calculated by dividing the total load emitted to the river by the discharge at Batujajar.

TABLE 25 THE MEASURED AND CALCULATED CONCENTRATIONS AT NANJUNG FOR THE WET AND DRY SEASON

(mg/l)	*Measured Wet*	*Measured Dry*	*Calculated Wet*	*Calculated Dry*	*Conservative Wet*	*Conservative Dry*
COD	27.9	47.3	48	471	51	573
BOD	10.5	21.8	12.1	77.5	19.4	218
Nitrate	1.1	1.4	0.2	0.95	0.2	2.3
Zinc	0.04	0.05	7.3E-05	7.4E-04	7.35-05	8.4-04
Fecal Coliform			3208	33128	3306	37134

Comparing the measured substances with the calculated substance it shows that COD is overestimated, where nitrate and zinc are underestimated. The results for BOD are in the wet season comparable with the measured values, but are overestimated for the dry season.

The deviation in the results has different causes. It is possible that the parameters used to calculate the loads are over- or underestimated. It is also possible that because the input parameters of the processes used in the model are not changed (except water temperature), these values are not a good representation of the processes in the Citarum river, but because this research is about giving a rough estimation about the values (and a lack of data on these processes), the parameters are not changed. The process parameters could be calibrated to get closer to the measured values, but this may not be reasonable as the exact emissions are unknown.

Besides calibrating the parameters to come to a better result, also adding more substances can have an effect on the concentration. Some substances do react with each other to other substances (e.g. ammonium and oxygen together gives nitrate). This causes that some substances can have a higher concentration in reality and some a lower. This can be a reason that nitrate is calculated lower compared to the reality.

The sources used for the different substances are also limited. In the calculation there are for instance no heavy metals coming from domestic. However, the roofing of houses can have zinc plates on them. Not taking into account all the different sources for the loads can lead to an underestimation of the concentration.

Another reason for the overestimation of some substances is the place where the loads are entering the river. For the Ciwidey basin this a very close to the place of measuring. Processes did not have much time to work on the substances from the basin and are therefore estimated too high.

The differences between the calculated and conservative values have to do with the processes playing part on the substances. The first-order process is visible in this table, because the reduction is larger when the substances have a higher concentration (dry season) than when the concentration is low (wet season). The anomaly in the table is nitrate. Here the conservative values are lower as the calculated values. This means that an extra source is producing nitrate. The assumption is made that one of the other substances is degraded into nitrate, BOD can degrade into nitrate via a nitrogenous process (included in SOBEK).

Even though there are large uncertainties in the estimated loads and model assumptions (discharge, processes, stationary), the model still produces concentrations in the same order of magnitude as the measured concentrations. This gives sufficient confidence that load estimations and model can be used to evaluate the relative effect of different scenarios.

5 SCENARIOS

The interviews with the stakeholders are used to define scenarios. To give the stakeholders more insight in were to start to improve the impaired water quality is key in this research. The solutions which are named the most by the stakeholders for the improvement of the water quality are put into scenarios. With the quantification of the emissions in previous chapter it is possible to estimate the changes in these emissions due to the different scenarios. This chapter gives the scenarios and the subsequent changes to the emission data.

The next scenarios are chosen to model:

Reference scenario	The current status in 2015 is used as reference scenario
Worst case scenario 2030	An autonomous growth of population and economy is combined with the current status of policies to come to a worst case scenario
Improved sanitation	The people without any sanitation facilities are given a septic tank
Livestock in communal barns	The dispersed cattle is concentrated on a few places in barns to control the emission
Changing crops	The paddy fields are changed into fields for dry crops
Changing industry	This are three scenarios in one. First all the industries are deleted from the system, secondly only the textile industry is deleted, and third the textile factories are converted to other types of industry

5.1 Reference scenario

This scenario is the current situation of the river. This situation is represented by the simulations of Chapter 4. The calculated concentration (Table 25) will be used as a reference to assess the effect of the different scenarios on water quality.

5.2 Worst case scenario 2030

When the authorities do nothing to improve the water quality, but the population and economy keeps on growing, this scenario can become reality.

The trend for population growth is an increase of 50 million in Indonesia in the next 15 years. This is an increase of 20 percent (Figure 24). This leads to an increase of domestic waste of also 20 percent. The assumption is made that the people are spreading evenly throughout the basin so every area gets 20 percent more people.

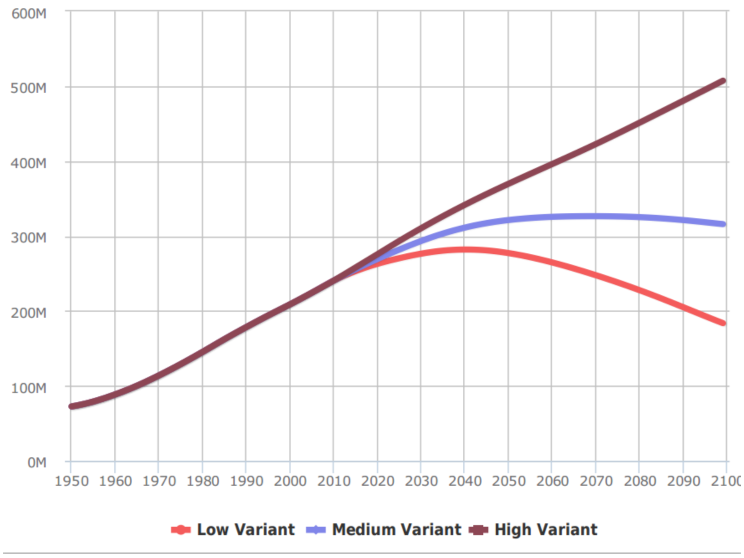


FIGURE 24 PREDICTION POPULATION GROWTH IN INDONESIA (WORLD POPULATION REVIEW, 2014)

Besides the population growth it is expected that also the economy will grow. This will result in an increase of industry and agriculture (crops and livestock) in the area. It is estimated that in order to produce enough for the growing population, Indonesia has to increase its agricultural production with 60 percent and its industrial production even with 75 percent (Oberman et al., 2012). It is assumed that also the loads coming from agriculture and industry increase which 60 and 75 percent, respectively. Also here the assumption is made that this is spread evenly throughout the basin.

TABLE 26 PERCENTAGES CHANGE OF THE LOADS FROM THE DIFFERENT LAND USE TYPES

Domestic	+20%
Industry	+75%
Agriculture	+60%

The new loads are calculated by multiplying the loads determined in Chapter 4 with the percentages in Table 26. This leads to the loads emitted to the river in the wet and in the dry season given in Table 27 and Table 28. The best way of showing what impact the change in emission is, is to compare it relatively with the status in 2015. Between brackets, behind the loads, is the change in percentages relative to the reference scenario. It shows that the amount of pollution in the river would increase a lot under this scenario.

TABLE 27 LOADS IN KG PER HOUR WHICH ARE EMITTED TO THE RIVER IN THE WORST CASE SCENARIO IN THE WET SEASON

(kg/h (%))	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	5127 (30)	1928 (30)	33 (54)	67 (23)	302057 (20)	0.03 (75)
Cirasea	1900 (44)	705 (43)	17 (57)	17 (23)	69194 (20)	0 (-)
Cisankuy	2365 (46)	929 (47)	12 (57)	18 (24)	79676 (20)	0.01 (75)
Citarik	10102 (24)	3862 (24)	23 (40)	152 (21)	3728374 (20)	0.004 (75)
Ciwidey	1271 (34)	448 (32)	13 (57)	16 (26)	64887 (20)	8.5E-05 (75)

TABLE 28 LOADS IN KG PER HOUR WHICH ARE EMITTED TO THE RIVER IN THE WORST CASE SCENARIO IN THE DRY SEASON

(kg/h (%))	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	4930 (29)	1870 (29)	13 (46)	63 (21)	300972 (20)	0.03 (75)
Cirasea	1785 (43)	672 (43)	5.4 (52)	15 (22)	68639 (20)	0 (-)
Cisankuy	2291 (46)	907 (47)	4.9 (52)	17 (21)	79350 (20)	0.01 (75)
Citarik	10023 (23)	3828 (23)	14 (29)	150 (20)	727918 (20)	0.004 (75)
Ciwidey	1170 (32)	419 (30)	4 (50)	14 (22)	64610 (20)	8.5E-05 (75)

5.3 Improved sanitation for people

The solution which almost all stakeholders gave in order to cope with the emission from the domestic environment, is better sanitation for the people (section 2.3). This means increasing the amount of people which have access to proper sanitation and improving the current system. A way to do this is by building more septic tanks. This can be done on communal basis or private.

It is estimated that around 25 percent of all the people in the Upper Citarum basin do not have access to any kind of sanitation and defecate directly in the river. This scenarios supplies them with a septic tank (Table 29).

TABLE 29 SANITATION OF THE PEOPLE PER SUBBASIN AND HOW FAR FROM THE RIVER WHEN ALL PEOPLE HAVE ACESS TO SOME SORT OF SANITATION (FROM TABLE 17)

District		*Between 0-100 meter*			*100 meter and further*		
People x1000	Total people	Total people	septic tank	no sanitation	Total people	septic tank	no sanitation
Cikapundung	3,178.8	36.7	14.7	0	3,142.1	1,256.9	0
Cirasea	721.7	19.2	7.7	0	702.5	281	0
Cisangkuy	837.4	12.1	4.9	0	825.3	330.1	0
Citarik	7,687.6	144.3	57.7	0	7,543.3	3,017.3	0
Ciwidey	675.3	46.7	18.7	0	628.6	251.4	0

The improved sanitation condition is used to calculate the emission from domestic. The characteristics described in section 4.3 stay the same. Only the amount of people per category changes. This gives the next emission for domestic (Table 30). This is a decrease of 57 percent relative to the emission in the reference scenario.

TABLE 30 LOADS IN KG PER HOUR WHICH ARE EMITTED TO THE RIVER FOR DOMESTIC ONLY WHEN ALL PEOPLE WITHOUT SANITATION GET A SEPTIC TANK

(kg/h)	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	1363	522	1.4	22	108302	0
Cirasea	310	119	0.3	5.0	24655	0
Cisangkuy	359	138	0.4	5.8	28548	0
Citarik	3301	1265	3.5	54	262247	0
Ciwidey	293	112	0.3	4.8	23243	0

Adding the new emission to the emissions from the other land use types gives the result presented in Table 31 and Table 32 with the relative change in percentages relative to the reference scenario between brackets behind the loads. It shows that this measure has effect on all the substances, except zinc (zinc is not emitted by persons).

TABLE 31 TOTAL LOADS IN KG PER HOUR WHICH ARE EMITTED TO THE RIVER IN THE SEPTIC TANK SCENARIO IN THE WET SEASON

(kg/h (%))	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	2416 (-45)	801 (-46)	19 (-9)	26 (-53)	109252 (-57)	0.015 (0)
Cirasea	913 (-31)	336 (-32)	10 (-4)	7.1 (-48)	25140 (-56)	0.000 (0)
Cisangkuy	1147 (-29)	452 (-29)	7.0 (-7)	7.2 (-52)	28833 (-57)	0.006 (0)
Citarik	3845 (-53)	1469 (-53)	12 (-29)	55 (-56)	262646 (-57)	0.002(0)
Ciwidey	563 (-41)	193 (-43)	7.8 (-5)	6.7 (-48)	23485 (-57)	4.88E-05 (0)

TABLE 32 TOTAL LOADS IN KG PER HOUR WHICH ARE EMITTED TO THE RIVER IN THE SEPTIC TANK SCENARIO IN THE DRY SEASON

(kg/h (%))	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	2023 (-47)	764 (-47)	6.9 (-21)	23 (-56)	108573 (-57)	0.015 (0)
Cirasea	841 (-33)	315 (-33)	3.1 (-12)	5.6 (-54)	24793 (-57)	0 (0)
Cisangkuy	1100 (-30)	438 (-29)	2.7 (-16)	6.2 (-55)	28629 (-57)	0.006 (0)
Citarik	3795 (-53)	1448 (-53)	5.9 (-44)	54 (-57)	262361 (-57)	0.002 (0)
Ciwidey	499 (-43)	174 (-46)	2.5 (-14)	5.3 (-54)	23312 (-57)	4.88E-05 (0)

5.4 Livestock in communal barns

A large problem in stockbreeding is that the manure is directly discharged to the river. There is no collecting system which collects the manure for the use of other purposes (compost- or biogas facilities). A reason for this is that the cattle is spread throughout the area. In the interviews (Chapter 2), the stakeholders gave as solution the concentration of the cattle in large communal barns. When doing this the manure can be collected easily and can be used in biogas or compost facilities.

Concentrating the cattle in communal barns leads to less discharge to the river when the manure is collected in large tanks (big septic tanks). To calculate the loads which still flow to into the river, the factor for septic tanks from Chapter 0 is used (0.4). Besides this the runoff coefficient per season from Table 7 is used (0.1% respectively 2% for the wet and dry season). This leads to a drop of 60 percent in the loads to the river) for stockbreeding.

The new loads of livestock are added to the loads of the other land use types to come to the total emission from all the land use types in the wet and dry season in this scenario (Tables 33Table 33 and 34). When comparing this to the loads in the reference scenario gives a relative decrease in emission shown between brackets in the same tables.

TABLE 33 LOADS EMITTED INTO THE RIVER PER AREA FOR THE WET SEASON WITH BETWEEN BRACKETS THE RELATIVE CHANGE COMPARED TO THE REFERENCE SCENARIO

(kg/h (%))	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	3832 (-2.6)	1455 (-2.1)	11 (-49)	53 (-3.8)	250828 (-0.2)	0.015 (0)
Cirasea	1260 (-4.6)	474 (-3.6)	4.7 (-56)	13 (-9.1)	57208(-0.5)	0.000 (0)
Cisangkuy	1579 (-2.4)	621 (-1.8)	3.9 (-48)	14 (-5.4)	66130 (-0.3)	0.006 (0)
Citarik	8136 (-0.5)	3117(-0.4)	11.8 (-26)	125 (-0.7)	606606 (-0.04)	0.002 (0)
Ciwidey	894 (-5.6)	324(-4.5)	3.7 (-55)	12 (-8.9)	53847 (-0.3)	4.88E-05 (0)

TABLE 34 LOADS EMITTED INTO THE RIVER PER AREA FOR THE DRY SEASON WITH BETWEEN BRACKETS THE RELATIVE CHANGE COMPARED TO THE REFERENCE SCENARIO

(kg/h (%))	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	3783 (-0.8)	1440 (-0.6)	5.8 (-34)	51.6 (-1.2)	250556 (-0.1)	0.015 (0)
Cirasea	1231 (-1.4)	466 (-1.1)	1.9 (-47)	11.9 (-2.9)	57070 (-0.1)	0.000 (0)
Cisangkuy	1560 (-0.7)	616 (-0.5)	2.2 (-32)	13.7 (-1.6)	66049 (-0.1)	0.006 (0)
Citarik	8117 (-0.1)	3104 (-0.1)	9.3 (-12)	124 (-0.2)	606492 (-0.01)	0.002 (0)
Ciwidey	868 (-1.7)	317 (-1.4)	1.6 (-45)	11.2 (-2.9)	53777 (-0.1)	4.88E-05 (0)

5.5 Changing crops

Agriculture has not a large impact on the pollution in the river (Figure 18), but it can be the straw that breaks the camel, therefore this scenario is conceived to check whether a change in agriculture can have a significant change on the overall concentration. Also in the interviews the stakeholders mentioned changing the kind of crops is a way of reducing the pollution in the river, because the current way is causing a lot of erosion. However, the suspended solids (coming from erosion) is no part in this research.

The change made in this scenario regards paddy fields. The crops cultivated on this lands have the highest average emission rate per hectare per growing season (Appendix C.1) therefore the effect is measured on the water quality when wet fields are eliminated completely. This is done in two ways. The first is eliminating them completely without changing it into other crops. The second is filling the vacant fields with crops from dry fields. The latter is done by dividing the vacant fields over the other crops relative to the occurrence of that crop.

For the calculation of the loads emitted to the lands the other parameters stay the same.

TABLE 35 EMISSION LOADS IN KILOGRAMS PER HOUR TO THE FIELD IN THE ORIGINAL SITUATION, WITHOUT PADDY FIELDS AT ALL, AND CHANGED TO OTHER CORPS ($E_{crop,i}$ IN FORMULA 1)

	Original loads			*Eliminating paddy fields*			*Converting paddy fields into dry crops*		
(kg/h)	BOD	Nitrate	Sulphate	BOD	Nitrate	Sulphate	BOD	Nitrate	Sulphate
Cikapundung	5.5	0.6	0.3	2.2	0.3	0.1	2.9	0.3	0.2
Cirasea	4.5	0.4	0.2	2.0	0.2	0.1	3.7	0.3	0.2
Cisangkuy	4.3	0.4	0.2	3.3	0.3	0.1	4.1	0.3	0.2
Citarik	272.3	21.8	10.9	269.5	21.6	10.8	271.9	21.8	10.9
Ciwidey	1.3	0.1	0.1	0.4	0.0	0.0	1.1	0.1	0.0

Table 35 gives the loads emitted to the land per area of all agricultural activities. This is without the runoff. The scenarios show a large decrease (Table 36) in emission when paddy fields are eliminated. Only in the Citarik area the change is very small. This is because in that area paddy fields are not a big portion of the agricultural activities.

TABLE 36 PERCENTUAL CHANGE RELATIVE TO THE ORIGINAL SITUATION

	Relative change when eliminating all paddy fields			*Relative change when converting vacant fields into dry crops*		
(%)	BOD	Nitrate	Sulphate	BOD	Nitrate	Sulphate
Cikapundung	-59.6	-52.8	-52.8	-46.8	-37.7	-37.7
Cirasea	-55.7	-57.1	-57.1	-16.2	-18.8	-18.8
Cisangkuy	-23.1	-24.5	-24.5	-6.4	-8.0	-8.0
Citarik	-1.0	-1.1	-1.1	-0.1	-0.2	-0.2
Ciwidey	-70.5	-72.2	-72.2	-14.3	-19.4	-19.4

The change in the total emission of all land use types to the water is not that big, because the emission from crop growing activities is only a small portion of the total. To calculate the run off to the river the same run off coefficient as in (section 4.1) is used. This leads to the next emissions for the wet and dry season and their relative change (Table 37 and Table 38) when the paddy fields are gone and the gaps are filled with other crops. Only this scenario is shown here, because the scenario when the paddy fields are left empty does have almost the same outcome in loads.

TABLE 37 LOADS EMITTED INTO THE RIVER PER AREA FOR THE WET SEASON WHEN THE PADDY FIELDS ARE CHANGED INTO OTHER CROPS WITH BETWEEN BRACKETS THE RELATIVE CHANGE IN PROMILLE COMPARED TO THE REFERENCE SCENARIO

(kg/h(‰))	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	3936 (-)	1486 (-0.06)	21.3 (-0.3)	55 (-0.07)	251398 (-)	0.015 (-)
Cirasea	1320 (-)	492 (-0.05)	10.5 (-0.2)	14 (-0.09)	57500 (-)	0 (-)
Cisangkuy	1618 (-)	633(-0.02)	7.5 (-0.1)	15 (-0.03)	66301 (-)	0.006 (-)
Citarik	8178 (-)	3129(-0.004)	16.1 (-0.1)	126 (-0.01)	606845 (-)	0.002 (-)
Ciwidey	947 (-)	340(-0.02)	8.2 (-0.1)	13 (-0.03)	53992 (-)	4.88E-05 (-)

TABLE 38 LOADS EMITTED INTO THE RIVER PER AREA FOR THE DRY SEASON WHEN THE PADDY FIELDS ARE CHANGED INTO OTHER CROPS WITH BETWEEN BRACKETS THE RELATIVE CHANGE IN PROMILLE COMPARED TO THE REFERENCE SCENARIO

(kg/h(‰))	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	3812 (-)	1449 (-0.02)	8.8 (-0.2)	52.2 (-0.02)	250719 (-)	0.015 (-)
Cirasea	1248 (-)	471 (-0.02)	3.6 (-0.2)	12.3 (-0.03)	57153 (-)	0 (-)
Cisangkuy	1572 (-)	619 (-0.004)	3.2 (-0.09)	14 (-0.01)	66098 (-)	0.006 (-)
Citarik	8128 (-)	3107 (-0.001)	10.5 (-0.05)	125 (-0.002)	606560 (-)	0.002 (-)
Ciwidey	883 (-)	321 (-0.006)	2.9 (-0.07)	11.5 (-0.009)	53819 (-)	4.88E-05 (-)

Where the change from wet fields to dry fields has a large effect on the emission from agriculture, the change in the total emission to the river is insignificant. The percentages change are very low compared to the other scenarios.

5.6 Changing Industry

According to the stakeholders the industries in the Upper Citarum Basin do not have or do not use a waste water treatment plant. Most of the waste water therefore is discharged into the river. The solution adduced is building more waste water treatment plants and more law enforcement, or changing the kind of industry in the area. To check the effects some scenarios are conceived. First a scenario in which there is no industry at all; the second is eliminating all the textile factories; and the third is changing the textile factories into other factories relative to the occurrence of that industry (see Appendix D).

5.6.1 No Industry

In this scenario the emission from all the industries is set to zero to check the effect of the industries on the total water quality. This leads to a drop in BOD and COD, a little decrease in nitrate and a complete elimination of the zinc. The latter is because industry is the only land use type in this research which emits zinc.

TABLE 39 LOADS EMITTED INTO THE RIVER PER AREA FOR THE WET SEASON WHEN THERE IS NO MORE INDUSTRY IN THE AREA WITH BETWEEN BRACKETS THE RELATIVE CHANGE COMPARED TO THE REFERENCE SCENARIO

(kg/h (%))	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	3325 (-16)	1260 (-15)	21 (-2.3)	55 (0)	251398 (0)	0 (-100)
Cirasea	819 (-38)	305 (-38)	11 (0)	14 (0)	57500 (0)	0 (-)
Cisangkuy	896 (-45)	338 (-47)	6.8 (-8.6)	15 (0)	66301 (0)	0 (-100)
Citarik	7704 (-5.8)	2955 (-5.6)	16 (-0.9)	126 (0)	606845 (0)	0 (-100)
Ciwidey	765 (-19.2)	285 (-16)	8.2 (-0.1)	13 (0)	53992 (0)	0 (-100)

There is a slight difference between the wet season (Table 39) and dry season (Table 40). In the dry season there is less pollution from agriculture and stockbreeding flowing into the river, so the relative change is bigger in the dry season.

TABLE 40 LOADS EMITTED INTO THE RIVER PER AREA FOR THE DRY SEASON WHEN THERE IS NO MORE INDUSTRY IN THE AREA WITH BETWEEN BRACKETS THE RELATIVE CHANGE COMPARED TO THE REFERENCE SCENARIO

(kg/h (%))	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	3202 (-16)	1223 (-16)	8.3 (-6)	52 (0)	250719 (0)	0 (-100)
Cirasea	757 (-40)	283 (-40)	3.6 (0)	12 (0)	57153 (0)	0 (-)
Cisangkuy	850 (-45)	324 (-48)	2.6 (-20)	14 (0)	66098 (0)	0 (-100)
Citarik	7654 (-6)	2933 (-6)	10.3 (-1.5)	125 (0)	606560 (0)	0 (-100)
Ciwidey	702 (-21)	267 (-17)	2.9 (-0.2)	12 (0)	53819 (0)	0 (-100)

5.6.2 Industry without textile factories

The textile industry is the most polluting, because it is absolute the biggest industry in the area (Table 21). Eliminating this should have a large impact on the water quality in the river.

For the emission from industry itself, deleting all the textile factories gives a big drop compared to with the original situation (Table 22). COD and BOD are almost gone in the emission from industries. The other substances stay the same because these are not coming from textile factories (percentages between brackets) (Table 41).

TABLE 41 LOADS FROM ONLY THE INDUSTRY WHEN THE TEXTILE FACTORIES ARE DELETED AREA WITH BETWEEN BRACKETS THE RELATIVE CHANGE COMPARED TO THE REFERENCE SCENARIO

(kg/h (%))	*COD*	*BOD*	*Nitrate*	*Sulfate*	*Coliform*	*Zinc*
Cikapundung	47 (-92)	22.5 (-90)	0.5 (0)	0 (-)	0 (-)	0.01 (0)
Cirasea	0 (-100)	0 (-100)	0 (-)	0 (-)	0 (-)	0 (-)
Cisangkuy	356 (-51)	160 (-46)	0.6 (0)	0 (-)	0 (-)	0.006 (0)
Citarik	15 (-97)	4.9 (-97)	0.2 (0)	0 (-)	0 (-)	0.002 (0)
Ciwidey	0.03 (-100)	0.009 (-100)	0.006 (0)	0 (-)	0 (-)	4.88E-05 (0)

The total emission in the wet and dry season (Tables 42 and 43) is most changed in the Cirasea area, because here industry is the only contributor (for this research) to the pollution (Figure 18).

TABLE 42 TOTAL OF LOADS EMITTED INTO THE RIVER PER AREA FOR THE WET SEASON WHEN THERE ARE NO MORE TEXTILE FACTORIES IN THE AREA WITH BETWEEN BRACKETS THE RELATIVE CHANGE COMPARED TO THE REFERENCE SCENARIO

(kg/h (%))	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	3373 (-14)	1282 (-14)	22 (0)	55 (0)	251398 (0)	0.015 (0)
Cirasea	819 (-38)	305 (-38)	11 (0)	14 (0)	57500 (0)	0 (-)
Cisangkuy	1253 (-23)	499 (-21)	7.5 (0)	15 (0)	66301 (0)	0.006 (0)
Citarik	7719 (-5.6)	2959 (-5.4)	16 (0)	1126 (0)	606845 (0)	0.002 (0)
Ciwidey	765 (-19)	285 (-16)	8.2 (0)	13 (0)	53992 (0)	0.000 (0)

TABLE 43 TOTAL OF LOADS EMITTED INTO THE RIVER PER AREA FOR THE DRY SEASON WHEN THERE ARE NO MORE TEXTILE FACTORIES IN THE AREA WITH BETWEEN BRACKETS THE RELATIVE CHANGE COMPARED TO THE REFERENCE SCENARIO

(kg/h (%))	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	3250 (-15)	1245 (-14)	8.8 (0)	52 (0)	250719 (0)	0.015 (0)
Cirasea	747 (-40)	283 (-40)	3.6 (0)	12 (0)	57153 (0)	0 (-)
Cisangkuy	1207 (-23)	485 (-22)	3.2 (0)	14 (0)	66098 (0)	0.006 (0)
Citarik	7669 (-5.6)	2938 (-5.5)	11 (0)	125 (0)	606560 (0)	0.002 (0)
Ciwidey	702 (-21)	267 (-17)	2.9 (0)	12 (0)	53819 (0)	0 (0)

5.6.3 Textile factories changed into other factories

In this scenario the textile factories are converted into other factories. These factories are from industries which also appear in the relevant sub basins (Table 21). So for the Ciwidey area the textile factories are divided among chemistry and tea processing facilities. This division is done by looking at the relative appearance in the total area. The industry which is the biggest after textile gets the most new factories and the smallest industry the least.

TABLE 44 PERCENTAGE OF TOTAL FACTORIES IN THE OLD AND NEW SITUATION

	Old situation		*New situation*	
Type	No	%	No	%
Textile	276	72.1	0	0
Pharmacy	19	5.0	68	17.8
Basic Metal	18	4.7	64	16.8
Food & Beverages	16	4.2	57	15.0
Chemical	11	2.9	39	10.3
Geothermal	8	2.1	29	7.5
Paint	5	1.3	18	4.7
Pulp and Paper	4	1.0	14	3.7
Tea processing	3	0.8	11	2.8
Others	23	6.0	82	21.5
Total	383	100	383	100

When looking at only the discharge from industry and the change this scenario causes compared to the reference scenario (Table 45), it can be noted that not all the substances drop. COD and BOD decrease a lot, but nitrate and zinc increase. This is because the factories which replace the textile factories emit more nitrate and zinc then textile factories.

TABLE 45 LOADS FROM ONLY THE INDUSTRY WHEN THE TEXTILE FACTORIES ARE CHANGED INTO OTHER FACTORIE WITH BETWEEN BRACKETS THE RELATIVE CHANGE COMPARED TO THE REFERENCE SCENARIO

(kg/h (%))	*COD*	*BOD*	*Nitrate*	*Sulfate*	*Coliform*	*Zinc*
Cikapundung	55 (-91)	26 (-88)	0.6 (14)	0 (-)	0 (-)	0.02 (16)
Cirasea	0 (-100)	0 (-100)	0 (-)	0 (-)	0 (-)	0 (-)
Cisangkuy	390 (-46)	174 (-41)	0.7 (11)	0 (-)	0 (-)	0.01 (12)
Citarik	17 (-96)	5.8 (-97)	0.2 (12)	0 (-)	0 (-)	0.003 (14)
Ciwidey	0.04 (-100)	0.006 (-100)	0.006 (10)	0 (-)	0 (-)	5.4E-05 (10)

The amount of factories per category is the only parameter which changes and this leads to new emission to the river. The emission from industry is again added with the other (unchanged) emissions to come to the total emission in the wet and dry season (Table 46 and Table 47).

TABLE 46 TOTAL LOADS EMITTED TO THE RIVER PER AREA IN THE WET SEASON WHEN THE TEXTILE FACTORIES ARE CHANGED WITH BETWEEN BRACKETS THE RELATIVE CHANGE COMPARED TO THE REFERENCE SCENARIO

(kg/h (%))	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	3380 (-14)	1286 (-14)	21 (0.3)	55 (0)	251398 (0)	0.017 (16)
Cirasea	819 (-38)	305 (-38)	11 (0)	14 (0)	57500 (0)	0 (-)
Cisangkuy	1286 (-21)	512 (-19)	7.5 (1.0)	15 (0)	66301 (0)	0.007 (12)
Citarik	7721 (-5.6)	2960 (-5.4)	16 (0.1)	126 (0)	606845 (0)	0.003 (14)
Ciwidey	765 (-19)	285 (-16)	8.2 (0)	13 (0)	53992 (0)	5.3E-05 (10)

TABLE 47 TOTAL LOADS EMITTED TO THE RIVER PER AREA IN THE DRY SEASON WHEN THE TEXTILE FACTORIES ARE CHANGED WITH BETWEEN BRACKETS THE RELATIVE CHANGE COMPARED TO THE REFERENCE SCENARIO

(kg/h (%))	*COD*	*BOD*	*Nitrates*	*Sulphate*	*Fecal Coliform*	*Zinc*
Cikapundung	3257 (-15)	1249 (-14)	8.9 (0.8)	52 (0)	250719 (0)	0.017 (16)
Cirasea	747 (-40)	283 (-40)	3.6 (0)	12 (0)	57153 (0)	0 (-)
Cisangkuy	1240 (-21)	497 (-20)	3.3 (2.2)	14 (0)	66098 (0)	0.007 (12)
Citarik	7672 (-5.6)	2939 (-5.4)	14 (0.2)	125 (0)	606560 (0)	0.003 (14)
Ciwidey	702 (-21)	267 (-17)	2.9 (0)	12 (0)	53819 (0)	5.3E-05 (10)

6 RESULTS SCENARIOS

In the previous Chapter the scenarios are elaborated and the change of the loads is given. These new loads are put into the SOBEK model at the input points in the sub catchments (Figure 19) to evaluate the effects on the water quality near Nanjung (measuring station in Figure 19). This is done for both the wet as the dry season. The results of the reference scenario (Chapter 4) are compared to these changed concentrations (Figure 25).

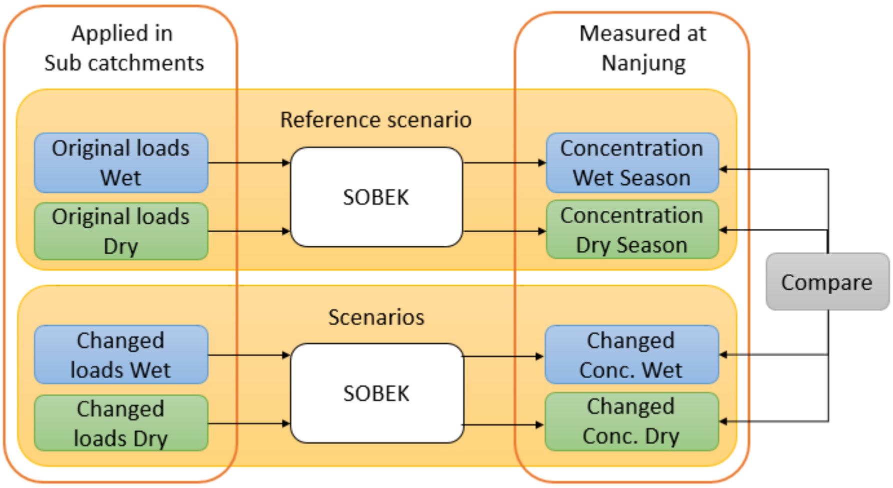


FIGURE 25 FLOWCHART ON HOW THE RESULTS ARE COMPARED

For each scenario new concentrations are determined (Table 48). These changed concentrations are placed alongside the original (reference scenario) situation in the table. It shows that the concentrations corresponding with the worst case scenario are, as expected, higher compared to the original situation. The other scenarios show for at least one substance a decrease in concentration. However, none of the scenarios deliver values which are below the MPC values. Only implementing septic tanks in the wet season can reach for fecal coliform a value below the MPC. For zinc the values are already below the MPC.

TABLE 48 THE CALCULATED CONCENTRATIONS BY THE SOBEK MODEL IN A RANGE. THE LOWER VALUE OF THE RANGE IS THE WET PERIOD AND THE HIGH VALUE GIVES THE CONCENTRATION IN THE DRY PERIOD. THE LAST COLLUMN IS THE MAXIMUM PERMISSABLE CONCENTRATION

mg/l	*BOD*	*COD*	*Nitrate*	*Zinc (xE-05)*	*Fecal coliform*
Original	12-77	48-471	0.20-1.0	7.3-7.4	3208-33129
Worst case	16-100	62-609	0.30-1.32	14-14	3853-39763
Septic tank	6-41	25-249	0.17-0.68	7.3-7.4	1392-14338
Communal barns	12-77	47-469	0.11-0.67	7.3-7.4	3204-33116
Eliminating Paddy fields	12-77	48-471	0.20-0.93	7.3-7.4	3208-33129
No industry	10-65	41-396	0.19-0.89	0-0	3208-33129
No textile factories	11-68	42-409	0.20-0.93	7.1-7.4	3208-33129
Textile changed into other	11-68	42-410	0.20-0.94	8.4-8.7	3208-33129
MPC	6	10	0.05	2000	1000

To clarify the comparison between the reference scenario and the other scenarios, the results are presented relative to the reference scenario (Figure 256 and Figure 7).

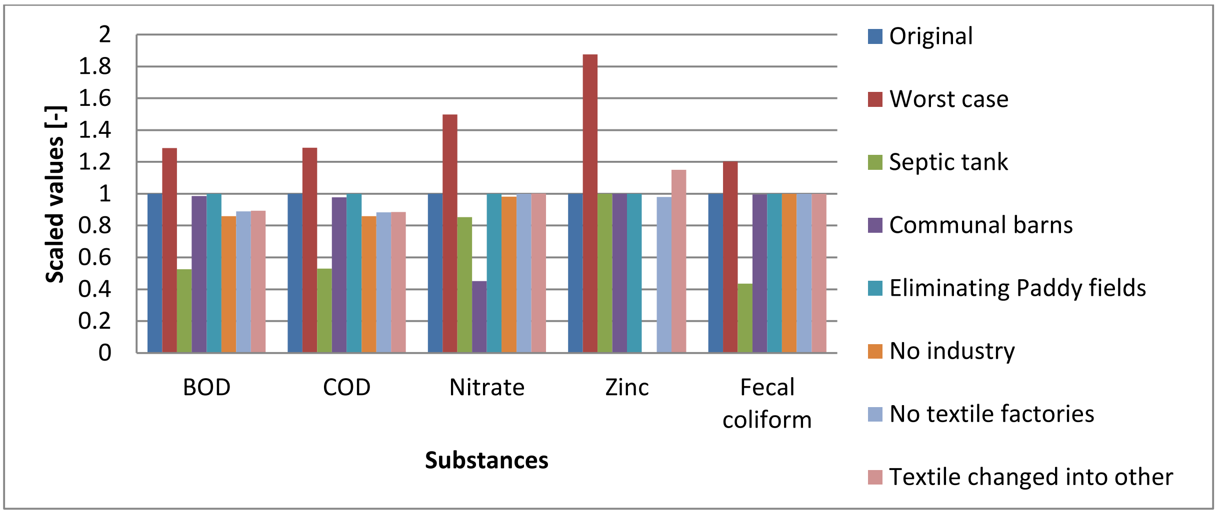


FIGURE 25 RESULTS OF THE SCENARIOS OF THE WET SEASON. THE RESULTS ARE SCALED TO THE REFERENCE SCENARIO

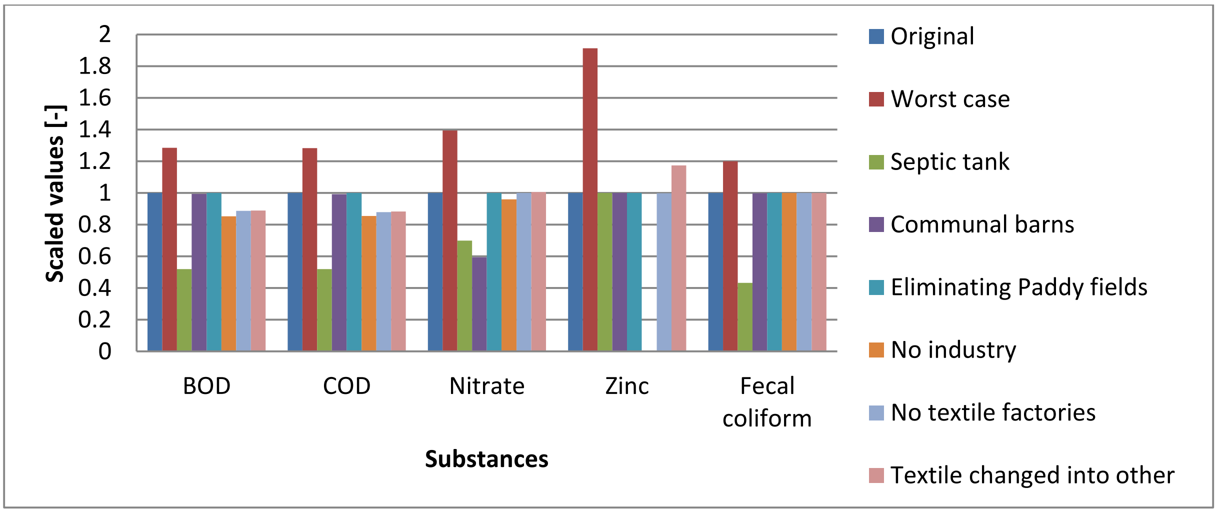


FIGURE 27 RESULTS OF THE SCENARIOS OF THE DRY SEASON. THE RESULTS ARE SCALED TO THE REFERENCE SCENARIO

The difference between the results in wet and dry season is most visible when looking at nitrate. Nitrate is most influenced by the season, because the largest producer of nitrate is livestock activities and this land use type is depending on the run off, therefore the difference is visible. Also the loads from crop growing activities are depending on the run off, but because this is a small contributor to the problems it is not visible in this figures. The substances which are coming most from households (BOD, COD and fecal coliform) and industry (zinc) show only small differences between wet and dry, because these substances are not depending on the run off.

In the worst case scenario the concentration in the river increases for all the substances. This is because the different land use types are increased in size and nothing is undertaken to counteract this. The concentration of zinc in this scenario is increased with almost 90 percent. This is because zinc is only originating from industry and industry is enlarged with 75 percent. The difference in percentages between loads and concentration (75% versus 90%) has to do with the saturation of the adsorption of zinc. The soil is saturated at a certain point and the remaining zinc flows downstream.

Not only in the worst case have scenario substances increased. For the scenario where the textile factories are changed into other industries, the concentration of zinc increases. The reason for this is that textile factories, in this research, do not emit zinc. Zinc comes from the other industries in the area. Increasing these industries logically leads to an increase in zinc.

The scenario with overall the best result is implementing septic tanks for the people who do not have sanitation facilities. Nitrate is decreased a bit, BOD and COD are almost halved, and fecal coliform even more as half. This large decrease is caused by the large amount of people present in the area. Domestic is the largest contributor to the problem (Figure 18), so improving something for this land use type should have a large effect on the concentration of the different substances in the river. Zinc is in this scenario untouched, because people are not emitting zinc.

The scenario with the least impact involves agriculture (eliminating paddy fields). Agriculture is not a large contributor to the pollution in the river (Figure 18) and the changes made lead also to very low changes in the total loads (Table 37 and 38) so changing something in this land use type has not a large effect on the improvement of the water quality.

7 DISCUSSION

The purpose of this research was to determine and calculate scenarios which give stakeholders handhold on what measures have a large effect and which less. Because of the reliability of the data and the amount of assumptions made, makes this research more a guideline then an instruction. The scenarios have to be compared to the other scenarios and not with the measured concentration.

In this chapter the important assumptions which have an influence on the input and outcome of this research are discussed.

7.1 Substances

In this research only six substances are used. This because of the lack of data and modeling all the substances would take a lot of time. Therefore only the most important substances are chosen, which are also representative for the four land use types. By choosing only six substances the processes among substances are limited. Some substances originate from a reaction between other substances (ammonium and oxygen gives nitrate) and some react to new substances. Only having this six substances limits the reactions between substances and therefore some substances will be overestimated and other substances will be underestimated. This can be seen in Table 25 where the calculated concentration of nitrate is lower than the measured concentration. Nitrate is produced by oxidation of ammonium (nitrification), but ammonium is not included in this model.

For the six substances the emission per land use type is determined. This is done by looking at processes which take place within a land use type, however not all processes are considered. For example the emission per person is taken into account for domestic, but substances coming from the building materials of houses or vehicles is not. The same goes for industry. Here only the processes within a factory are considered. The building which houses the factory is left out. This causes that some substances are presented lower than in reality.

7.2 Measured concentration data

Measured data is used to determine the severity of the problem and to verify whether the outcome of the model reliable is or not. In the comparison between the calculated concentration and the measured concentration, data is used from PJT-II. This organization measures the water quality once every month. The measured data therefore is in a moment of time. It is possible that the water quality is, for some reason, at the moment of measuring, is worse or better as usual. This means that the data which is used for the comparison can be an overestimation or underestimation. A consequence of this is that the conclusion drawn in section 4.7 (the calculated outcome is within the same order of magnitude and that enough confidence is given to model the scenarios) is based on less reliable data. This does not change the outcome of the model, but changes the confidence of the outcome.

7.3 Emission determination

Assumptions are made when determining the emission from the different land use types. These assumptions are based on literature. The figures founds were based on other basins in the world and the figures found on the Citarum Basin (as pointed out in chapter 4) can be doubted. A subdivision is made to discuss the assumptions and which assumptions are more important in the process of calculation. The assumptions used can be put into three categories: Key assumptions, important assumptions and less important assumptions.

TABLE 49 ASSUMPTIONS MADE IN THE DETERMINATION OF THE EMISSION FROM THE LAND USE TYPES

Key assumptions	Important assumptions	Less important assumptions
Run off coefficients	Emission per crop	Hectares per crop in the basin
Percentages of people access to sanitation	Emission per animal	Number of animals present in the basin
Percentages of grey and black water in waste water	Emission per person	Number of people in the basin
Size of unregistered industry	Emission per industry	

The key assumptions are constants which have a large influence on the loads entering the river and which, when determined, do not change. For example changing the run off coefficient gives more pollution to the river, but when the run off is determined for the basin, it will be a given. The important assumptions are values (in this case, emissions) which act always within a certain range and are likely to change within this range because the emission is different per entity and it depends on the moment in time. In this research the emission values are averaged and are for every person, every animal, every hectare or every factory the same. Changing these values has a large influence on the water quality. The less important assumptions are assumptions which when they change, do not have a large effect on the concentration unless they change in great numbers (an extra person does not change the concentration much, an extra million does) and because of the growing population and economy are most likely outdated already. They do not act within a range, but are ever growing.

In the next section the key assumptions are explained more in detail.

7.3.1 Run off coefficients

The run off coefficients used in the determination of the emission per land use are fixed for the whole basin. For agriculture and stockbreeding the run off is divided in wet and dry season. The run off coefficient in domestic is divided in distance to the river. However a run off coefficient is not only depending on rain or distance to the river, but also on the relief of the area, the soil, the paved surface and saturation level. This causes that the concentration changes when different run offs would be used.

For stockbreeding the run off coefficient is applied to the emission of all animals. Also on the animals which live in a barn. In this research no division is made between barn animals and free animals, because the percentage of animals living is barns could not be found. The run off coefficient is applied on all the animals, because the assumption is made that most animals live freely on the fields (based on the experience of the writer of this report). The run off coefficient which should be applied on animals in the barns is 100 percent, because the waste from animals in barns is washed into the river completely when the farmers clean the barns (see section 2.2). Therefore the emission from stockbreeding is presented too low.

7.3.2 Sanitation accessibility

In the calculation of the emission from households some assumptions are made which relates to sanitation:

- The access to sanitation is, in this research, depending on whether the people live in a city or in a more rural environment. The assumption is made that in the city more people have access to a sewage system.
- The waste water discharged by sewage systems is all treated and nothing is leaked to the surface water.
- It is also assumed that all the septic tanks have the same leakage/spillage percentage of 40 percent.
- All waste water from people without any sanitation is directly discharged into the river.

These assumptions can be disputed because most of the sewage systems in Bandung are still from the Dutch period (ADB, 2013), therefore rather old and a good change they are leaking. Not all septic tanks leak that much or even more; and not all people without sanitation defecate in the river. The emissions calculated in this research changes when assuming other values for the percentages used.

7.3.3 Grey and black water

The division between grey and black water is based on data from developed countries. Indonesia is a developing country. It is assumed that the less industrialized a country is, the less black water (proportionally) a person produces. Less black water leads to less fecal coliform for example. Because the large amount of people in the Citarum Basin, such an assumption can have large influences on the water quality

7.3.4 Size unregistered industries

To determine the size of the unregistered industry, the assumption from the government is adopted. However the way this assumption is made, is unknown and therefore the size is questionable. A lot of the unregistered industries are home industries, like bakeries, sewing workshops etc. The number is hard to guess. The land use 'industry' is a large polluter in some areas and therefore changing the size of registered industries can have a large impact on the water quality.

7.4 Model

In the SOBEK model a lot of parameters can be calibrated to represent the reality as good as possible. For this research however all the parameters are kept on the default settings. This is done because SOBEK is a very extensive program with a lot of complicated settings and calibrating a model to come to a value comparable with a value which itself is also questionable, seems not correct. The effect of adding the calibration and validation step to the process (when the data sets are at disposal) is that the confidence of the outcome of the model is improved and that the understanding of what is going on in the program is clarified.

The model is used to come to a concentration based on the emission determination done in this research. This concentration value is then used as reference for the calculated concentrations with the scenarios. This way the scenarios all have the same basis and with the same parameters the conclusion stays the same when using a calibrated model.

7.5 Results

The results of this research are the outcomes of the scenarios in SOBEK. These results are calculated with defaults settings of the model and the same assumptions as in the determination of the reference scenario. Therefore the conclusions drawn on the results do not change when changing some parameters, as long as they are changed for all scenarios.

The concentrations coming from the scenarios calculated at the end of 2015. The implementation in the field of the measures used in the scenarios takes time. Before all the measures are implemented the population, industry and agriculture are already increased. The effect of the scenarios in reality are therefore smaller than predicted in this report.

8 CONCLUSIONS

The goal of this research was to determine and calculate scenario which give stakeholders a handhold on what measures have a large effect and which less. This is done by developing scenarios. These scenarios are based on alternative land use and water quality management as suggested in interviews with involved stakeholders.

This final Chapter presents answers to the research questions based on the goal of this research, as posed in chapter 1.

1. *What are, according to the different authorities, the causes of and possible solutions for the impaired water quality in the Citarum River? (Chapter 2)*

Stakeholders
The stakeholders interviewed were people from the local, provincial and national government which have authority on water quality; a non-governmental organization (NGO) which tries to raise awareness of the problem in the Citarum River; and an organization for the water quality managers of the industry. In the answers given by these stakeholders it was noted that the different stakeholders gave apart from each other almost the same answers, therefore no distinction is made between the different stakeholders.

Causes and solutions
Domestic waste is the largest polluter in the area, because of the number of people living in the area. Not all people are connected to a sort of sanitation and dump their waste directly in the river or on the lands. The waste water from people with a sanitation facility is not always fully treated. The waste water treatment plants are old, septic tanks are leaking or are not emptied on time. The solution is, easily said, building more waste water treatment plants, more connections to the sewage systems and more septic tanks for the people in rural areas. The government should then hire more truck drivers to empty the septic tanks.

For agriculture the problems were the scarcity of the land, which lead to the cultivation of the hills and erosion, and the unfamiliarity of the farmers with fertilizers and pesticides. The latter makes that farmers use too much of it or use it illegally. The solution to these problems is educating the farmers on the use of fertilizers and pesticides, and planting perennial crops.

For stockbreeding the problems are the spreading of the animals throughout the basin. The manure is not collected and washed directly into the river. Built biogas facilities do not work because there are not enough animals near to keep it running and the people are not educated to work with it. A solution to the problems is the relocation of animals into communal barns. The manure can then easily be collected and used in the biogas facilities. Educating the farmers on the usage of the facilities is then a logical consequence.

The industry in the Upper Citarum basin can be divided into registered and unregistered industry. The registered industry is obliged to have treatment of the water, but this costs money and therefore this is not always done. The government does not have enough inspectors to check all the factories, so a lot of industries do not bother of treating their waste water. The unregistered industries are small factories at people's homes which are hard to detect and control. The solution is more inspectors which enforce the law on waste water treatment and a centralized waste water treatment plant, run by the government.

2. *What are the estimated loads and resulting concentrations of the most relevant substances to the Citarum River? (Chapter 3+4)*

Based on the water quality data the most relevant substances to model are: Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), nitrate, sulphate, fecal coliform and zinc. This also gives a representation of the different land uses. Unfortunately, sulphate cannot be modelled in SOBEK, therefore it is not in the final calculations.

The loads of these substances are determined by estimating the load of a single unit per land use type and adding the total as input to the SOBEK model to calculate the concentrations at the end of the Upper Citarum Basin (Nanjung). The calculated loads show that domestic is by far the largest polluter in the area for COD, BOD, fecal coliform and sulphate. Stockbreeding causes the highest emission for nitrate. Zinc is an anomaly because it is only emitted by industry.

These concentrations are then compared to the measured concentrations to check whether the estimations are accurate. In the comparison it shows that COD is overestimated, where nitrate and zinc are underestimated. The results for BOD are in the wet season comparable with the measured values, but are overestimated for the dry season. The deviation in the calculated compared to the measured values has to do with the assumptions made. The amount of substances chosen; the emission parameters change the input in the SOBEK model; the model parameters change the outcome; and the amount of processes which determine the input values, all lead to a deviation between the measured and calculated values.

Even though there are large uncertainties in the estimated loads and model assumptions (discharge, processes, stationary), the model still produces concentrations in the same order of magnitude as the measured concentrations.

3. *What are suitable scenarios for the Citarum River Basin and the associated changes in loads? (Chapter 5)*

The interviews and the concentration data are used to determine a few scenarios. The scenarios chosen are:

- Reference scenario
- Worst case scenario
- Improvement of sanitation
- Communal barns for the cattle
- Changing crops
- Changing industries

The scenarios represent changes in land use or taking action to reduce emission from a given type of land use. The purpose of the scenarios is to lower the concentration of all the substances in the river compared to the reference scenario. The exception is the worst case scenario. This has to be a deterrent when no improvements are made, but the population and economy keeps on growing. For the other scenarios goes that the water quality overall improves. Not all substances change for each scenario, but mostly the associated concentration drops.

4. *What are the most promising scenarios based on their effect on water quality? (Chapter 6)*

Based on the effect of the water quality, giving septic tanks to people without any sanitation is the most promising. This leads to the biggest drop for BOD, COD and fecal coliform. The biggest drop in nitrate is when putting the cattle in communal barns. These scenarios are also relatively feasible, because this can be enforced by the government where the other scenarios need more powerful people involved (industries).

9 RECOMMENDATIONS

Based on this research multiple recommendations can be made. Recommendations for further research as well for improving the model.

9.1 Further research

The assumptions made in this research are based on one source on the water quality in the Upper Citarum basin and on literature of other basins in the world. The circumstances in the Upper Citarum Basin are not always comparable to the areas used in the literature. Therefore more research has to be done on the emissions from the different land uses in the Upper Citarum Basin to verify the input of emissions.

- More data on the emission from the different industries
- Data on the emission and location of the unregistered industries
- More detailed information on the division of crops throughout the basin and the emission in time
- More data in the application of fertilizers and pesticides in the basin
- The amount and location of animals throughout the basin
- Better prediction on the amount of people access to some sort of sanitation
- The spills in the sewage systems and septic tanks

9.2 Improving input for the model

The run off in this research is aligned for the whole basin. An improvement for the reliability of the outcomes is the use of multiple run off coefficients for different areas of the basin (as pointed out in the Discussion). Also a better division in domestic between city and rural is desirable. The expectation is risen that some areas in the city are connected to the sewage system and others are not. This leads that there is a different discharge of pollution for different areas in the city, unlike is said in this research where the discharge from the city is aligned.

When more data from the different land uses and the different run off coefficients can be obtained, it is possible to divide the area in smaller sub basins. In this research only five sub basins are taken into account which each its own emission point. In the most idealized situation a model can be build where at each segment in the river the concentration can be determined. Therefore a very fine grid of emission points is needed and consequently more refined data. This all leads to a better view on the impaired water quality and would hopefully increase the decisiveness to tackle the problems.

9.3 Improving the model

In this research the parameters in the model are kept on their default settings. A calibration/validation step is missing, because of the lack of data. A recommendation for improving the model outcome is calibration and validation of the model. This leads to a more reliable outcome. To do so more data on the concentration in the Citarum river is needed.

When it appears that not enough data is found to calibrate/validate the model, a simpler model should be used. A simple model build in excel can also be a way to calculate the concentrations. A comparison between the SOBEK model and an excel model is not done in this research. Therefore this is a recommendation to investigate.

9.4 Scenarios

The scenarios show a decrease in concentrations at Nanjung, however not one scenario shows values below the MPC. This means that the measures separately are not enough to improve the water quality sufficiently. A recommendation is to combine the scenarios to look whether the water quality drops below the maximum permissible concentration.

10 BIBLIOGRAPHY

Almy, F. M. (2008). Sustainability Assessment on Sanitation Systems for Low Income Urban Areas in Indonesia, 121.

ADB. (2013). Downstream Impacts of Water Pollution in the Upper Citarum River , West Java , Indonesia, (October).

Berenzen, N., Lentzen-Godding, A., Probst, M., Schulz, H., Schulz, R., & Liess, M. (2005). A comparison of predicted and measured levels of runoff-related pesticide concentrations in small lowland streams on a landscape level. *Chemosphere*, *58*, 683–691. doi:10.1016/j.chemosphere.2004.05.009

Biisser, S., Nga, P. T., Moree, A., & Ante, N. V. (n.d.). CHARACTERISTICS AND QUANTITIES OF DOMESTIC WASTEWATER IN URBAN AND PERI-URBAN HOUSEHOLDS IN HANOI Key words : Back water , grey water , Hanoi , household , loads , wastewater . Background The wastewater flows in Vietnamese HHs (HH) are greywater from ki.

Bond, T., & Templeton, M. R. (2011). History and future of domestic biogas plants in the developing world. *Energy for Sustainable Development*, *15*(4), 347–354. doi:10.1016/j.esd.2011.09.003

Campos, H. M., & Von Sperling, M. (1996). Estimation of domestic wastewater characteristics in a developing country based on socio-economic variables. *Water Science and Technology*. doi:10.1016/0273-1223(96)00558-6

Casanova, L. M., Gerba, C. P., & Karpiscak, M. (2001). Chemical and microbial characterization of household graywater. *Journal of Environmental Science and Health. Part A, Toxic/hazardous Substances & Environmental Engineering*, *36*(4), 395–401. doi:10.1081/ESE-100103471

Collins, N.-A. (2009, October 27). ADB Gives Indonesia 500 Million Dollar to Clean Up World's Dirtiest River. *Voice of America*.

Craswell, E. T., & Karjalainen, U. (1990). Recent research on fertilizer problems in Asian agriculture. *Fertilizer Research*, *26*(Table 1), 243–248. doi:10.1007/BF01048762

Deltares. (2011). Volume 1 : Strategic Flood Management Strategy, *1*(May).

Deltares. (2015). *SOBEK D-Water Quality User Manual.* Delft: Deltares.

EPA. (2015, 2 11). *Human Health Benchmarks for Pesticides*. Opgeroepen op 2 11, 2015, van United States Environmental Protection Agency: http://iaspub.epa.gov/apex/pesticides/f?p=HHBP:home

Fares, Y. R., & Yudianto, D. (2003). Assessment of hydrological characteristics in the upper Citarum catchment, West Java. *River Basin Management Ii*, *7*(May), 165–176. Retrieved from <Go to ISI>://WOS:000184464000016

Feder, G., Murgai, R., & Quizon, J. (2008). “Investing in Farmers-The Impacts of Farmer Field Schools in Relation to Integrated Pest Management”-A Comment. *World Development*, *36*(4), 2103–2106. doi:10.1016/j.worlddev.2008.04.011

French, D. (1986). Confronting an unsolvable problem: Deforestation in Malawi. *World Development*, *14*, 531–540. doi:10.1016/0305-750X(86)90068-9

Fulazzaky, M. A., Hadimuljono, M. B., Tun, U., Onn, H., Pahat, B., & Baru, K. (2008). Evaluation of the suitability of Citarum river water for different uses. *Water*, 1–14.

Groenink, I., & Schuurman, J. (2014, july 7). Citarum: Een rivier van uitersten. *Verspers, 10*(13).

Hyde, W. F., & Seve, J. E. (1993). The economic role of wood products in tropical deforestation: the severe example of Malawi. *Forest Ecology and Management*, *57*, 283–300. doi:10.1016/0378-1127(93)90178-P

Imhof, B., & Mühlemann, J. (2005). G Reywater Treatment on Household Level in Developing Countries –. *Water*, 98.

Iskandar. (2013). Inventarisasa & Identifikasi Sumber dan Beban Pencemaran Air. *Pengelolaan Kualitas Air*, 50.

Keeney, D. R. (1973). *The nitrogen cycle in sediment water systems.* Environ Quality.

Konradsen, F., Van Der Hoek, W., Cole, D. C., Hutchinson, G., Daisley, H., Singh, S., & Eddleston, M. (2003). Reducing acute poisoning in developing countries - Options for restricting the availability of pesticides. *Toxicology*, *192*, 249–261. doi:10.1016/S0300-483X(03)00339-1

Llewelyn, R. V., & Williams, J. R. (1996). Nonparametric analysis of technical, pure technical, and scale efficiencies for food crop production in East Java, Indonesia. *Agricultural Economics*, *15*, 113–126. doi:10.1016/S0169-5150(96)01202-9

Mancini, J. L. (1978). Numerical estimates of coliform mortality rates under various conditions. *Journal Water pollution control Federation*, 2477-2484.

Mangan, L. (2014, april 11). The World's Dirtiest River TV review - A visit to a paradise under threat. *The Guardian*.

Martin, P., & Wheeler, D. (1995). The Industrial Pollution Projection System, (March).

Mcdowell, R. W., Sharpley, a. N., Condron, L. M., Haygarth, P. M., & Brookes, P. C. (2001). Processes controlling soil phosphorus release to runoff and implications for agricultural management. *Nutrient Cycling in Agroecosystems*, *59*, 269–284. doi:10.1023/A:1014419206761

Ministerie van Verkeer en Waterstaat. (1998). *Vierde Nota waterhuishouding Regeringsbeslissing.* Den Haag.

Nibbering, J. W. (1999). Tree planting on deforested farmlands, Sewu Hills, Java, Indonesia: Impact of economic and institutional changes. *Agroforestry Systems*, *46*(1997), 65–82. doi:10.1023/A:1006202911928

Nilaparvata lugens,. (1996). *Management*, *41*(314), 375–385.

Oberman, Raoul, & Dobbs, Richard, & Budiman, Arief, & Thompson, Fraser, & Rosee, M. (2012). The Archipelago Economy: Unleasing Indonesia's Potential, (September), 1–116.

Parikesit, Takeuchi, K., Tsunekawa, a., & Abdoellah, O. S. (2005). Kebon tatangkalan: A disappearing agroforest in the Upper Citarum Watershed, West Java, Indonesia. *Agroforestry Systems*, *63*, 171–182. doi:10.1007/s10457-004-1182-x

Partowijoto, B. H. A. (2006). Monitoring and studies on water quality in some rivers and related water bodies in indonesia, *6*(February), 14–16.

Poor, C. J., & McDonnell, J. J. (2007). The effects of land use on stream nitrate dynamics. *Journal of Hydrology*, *332*, 54–68. doi:10.1016/j.jhydrol.2006.06.022

Prihandrijanti, M., & Firdayati, M. (2011). Current Situation and Considerations of Domestic Waste- water Treatment Systems for Big Cities in Indonesia (Case Study : Surabaya and Bandung), *1*(2), 97–104.

Sahu, N., Behera, S. K., Yamashiki, Y., Takara, K., & Yamagata, T. (2012). IOD and ENSO impacts on the extreme stream-flows of Citarum river in Indonesia. *Climate Dynamics*, *39*, 1673–1680. doi:10.1007/s00382-011-1158-2

Sonzogni, W. C., Chesters, G., Coote, D. R., Konrad, J. C., Jeffs, D. N., Ostry, R. C., & Robinson, J. B. (1980). Pollution from land runoff. *Environmental Science & Technology*, *14*(July 1978), 148–153. doi:10.1021/es60162a003

Sriwana, T., Van Bergen, M. J., Varekamp, J. C., Sumarti, S., Takano, B., Van Os, B. J. H., & Leng, M. J. (2000). Geochemistry of the acid Kawah Putih lake, Patuha Volcano, West Java, Indonesia. *Journal of Volcanology and Geothermal Research*, *97*, 77–104. doi:10.1016/S0377-0273(99)00178-X

Sullivan, A. B., Snyder, D. M., & Rounds, S. A. (2010). *Controls on biochemical oxygen demand in the upper Kalmath River, Oregon.* Elsevier. doi:doi:10.1016/j.chemgeo.2009.08.007

Sunarsih, S., Purwanto, P., & Budi, W. S. (2013). Management Efforts of Domestic Wastewater in Urban Based on Socio-Economic Variables. *Environmental Management and Sustainable Development*, *2*(2), 29–40. doi:10.5296/emsd.v2i2.3668

Van den Berg, H., & Jiggins, J. (2007). Investing in Farmers - The Impacts of Farmer Field Schools in Relation to Integrated Pest Manangement. *Elsevier*, *35*(4), 663–686.

Van Ginkel, C. H. (2015). Water quality of the Bandung Basin: towards a better understanding of the water quality of the Upper Citarum River Basin.

Widodo, T. W., Technos, C., Widodo, T. W., Tokumoto, O., & Office, T. (n.d.). SUGGESTION ON UTILIZATION OF FECES AT LARGE SCALE, 1–11.

Willis, H. (1983). Pesticides in Agricultural Runoff and Their, *1*.

World Population Review. (2014). *Indonesia Population 2014*. Retrieved 1 21, 2015, from World Population Review: http://worldpopulationreview.com/countries/indonesia-population/

APPENDIX A: QUALITY STANDARDS

TABLE 50 (ASSESSMENT & QUALITY, 2013; PARTOWIJOTO, 2006; EPA, 2015; MINISTERIE VAN VERKEER EN WATERSTAAT, 1998)

Parameter	*Unit*	*Indonesian quality Standards*	*Dutch quality standards*
Physics			
Temperature	^{o}C	Normal	25
Dissolved Solids	mg/l	1000	
Chemistry			
pH	mg/l	6 - 9	6.5 - 9
Dissolved Oxygen (DO)	mg/l	Required > 3	5
Iron (Fe)	mg/l	5	
Mangan (Mn)	mg/l	0.5	
Zinc (Zn)	mg/l	0.02	0.0094
Ammonia (NH_3-N)	mg/l	0.02	
Nitrite (NO_2-N)	mg/l	0.05	
Nitrate (NO_3-N)	mg/l	0.05	11.3
Sulphate (SO_4)	mg/l	400	100
Chloride (Cl)	mg/l	600	200
Sulphide (H_2S)	mg/l	0.002	
BOD	mg/l	6	
COD	mg/l	10	
Phosphate (PO_4)	mg/l	0.2	0.15
Cadmium	mg/l		0.0004
Chromium	mg/l	0.05	0.0087
Copper	mg/l		0.0015
Lead	mg/l		0.011
Mercury	mg/l		0.0002
Fluor	mg/l		1.5
Phenol	mg/l	0.001	
Fecal coliform	Units/l	1000	
Total coliform	Units/l	5000	

APPENDIX B: FORMULAS EMISSION ESTIMATION AGRICULTURE AND STOCKBREEDING

The method used in Chapter 4 to calculate the emissions is only valid when data is available which has measured in gram per acre per plant season. When this is not the case other ways have to be found to still calculate the emission.

B.1 Agriculture

B.1.1 With data source in *"g/ha/ plant season"* (used in Chapter 4)

$$L_{crop} = \sum_{i=1}^{n} \frac{E_{crop,i} \times A}{T} \times \alpha \quad (5)$$

With:

- L_{crop} is the total agricultural emission [kg/hour] to the river
- $E_{crop,i}$ is the average crop (i) emission of a certain crop type per growing season (g/ha/plant season)
- T is the length of plant season [h] in hours from harvesting in which a crop is fully grown and harvested
- A [ha] is the total surface area of a certain crop in a sub basin
- α is the run off coefficient [-] is a percentage of the total amount of substance which flows into the river
- n is the type of crop

B.1.2 With data source in *"ppm/spray time"*

This equation is usually used for the type of data source which shows the use of pesticide or fertilizer which is applied for the crops per yield.

$$L_{crop} = \sum_{i=1}^{n} \frac{E_{crop,i} \times V \times \gamma}{T} \times \alpha \quad (6)$$

With:

- L_{crop} is the total agricultural emission [kg/hour] to the river
- $E_{crop,i}$ is the average crop (i) emission of a certain crop type per growing season (g/ha/plant season)
- V the volume of pesticide or liquid fertilizer application for every crop type in UCR Basin
- γ is the frequency of pesticide or liquid fertilizer application for every crop type per plant season (spray time/ plant season)
- T is the length of plant season [h] in hours from harvesting in which a crop is fully grown and harvested
- α is the run off coefficient [-] is a percentage of the total amount of substance which flows into the river

- n is the type of crop

B.2 Stockbreeding

B.2.1 With data source in *"mg/ kg/ day"*

This equation is not only based on the number of animals, but also on kg-animal weight.

$$L_{Stockbreeding} = E_{Stockbreeding,j} \times N \times W \times \alpha \quad (7)$$

With:

- $L_{Stockbreeding}$ is the total emission [$\frac{kg}{hour}$] to the river from stockbreeding activities
- $E_{Stockbreeding,j}$ is the emission per animal (j) per day [$\frac{mg}{animal.day}$]
- N is the number of animals [-] in a certain area of a certain species
- W is the average weight of every cattle type (kg)
- α is the run off coefficient

B.2.2 With data source in *"g/l/time"*

This unit usually used for the amount of antibiotics used. Need to know the frequency of the injection of the antibiotics, the volume of the antibiotics used and the duration of producing lives of the animals.

$$L_{Stockbreeding} = \sum_{j=1}^{n} \frac{E_{Stockbreeding,j} \times V \times F}{T} \alpha \quad (8)$$

- $L_{Stockbreeding}$ is the total emission [$\frac{kg}{hour}$] to the river from stockbreeding activities
- $E_{Stockbreeding,j}$ is the emission per animal (j) per day [$\frac{mg}{animal.day}$]
- V is the volume of antibiotics used per injection
- F is the frequency of which the antibiotics are applied
- T is the time an animal is useful for production or growing
- α is the run off coefficient
- n is the type of animal

APPENDIX C: TABLES EMMISSION ESTIMATION AGRICULTURE AND STOCKBREEDING

In this appendix the emission estimation for agricultural activities and stockbreeding are given. These estimations contain the whole Upper Citarum Basin.

C.1 Estimated emission of crops to the land per sub basin

TABLE 51 PER CROP TYPE THE AREA, DAYS OF GROWING AND THE AVERAGE EMISSION IN THE CIKAPUNDUNG AREA

Cikapundung			*BOD*		*Nitrate*		*Sulphate*	
	Area (ha)	Plant Season (days)	Average emission (g/ha/plant season)	**Emission Estimation (kg/hour)**	Average emission (g/ha/plant season)	**Emission Estimation (kg/hour)**	Average emission (g/ha/plant season)	**Emission Estimation (kg/hour)**
WET FIELDS								
Paddy	34909	120	225	**2.7272**	20	**0.2424**	10	**0.1212**
water spinach	709	30	225	**0.2216**	20	**0.0197**	10	**0.0098**
DRY FIELDS								
Paddy	4418	120	225	**0.345**	20	**0.0307**	10	**0.0153**
Corn	1874	100	125	**0.098**	10	**0.0078**	5	**0.0039**
Soya bean	393	90	125	**0.023**	10	**0.0018**	5	**0.0009**
Peanuts	637	100	125	**0.033**	10	**0.0027**	5	**0.0013**
Long beans	407	100	125	**0.021**	10	**0.0017**	5	**0.0008**
Cassava	1937	270	125	**0.037**	10	**0.0030**	5	**0.0015**
Sweet potato/yam	474	120	125	**0.021**	10	**0.0016**	5	**0.0008**
Vegetables								
Chili	703	65	125	**0.056**	10	**0.0045**	5	**0.0023**
Red Onion/ Shallot	138	80	125	**0.009**	10	**0.0007**	5	**0.0004**
Chive	492	90	125	**0.028**	10	**0.0023**	5	**0.0011**
Tomato	921	65	125	**0.074**	10	**0.0059**	5	**0.0030**
Collards/ chicory	545	70	125	**0.041**	10	**0.0032**	5	**0.0016**
Potato	372	120	125	**0.016**	10	**0.0013**	5	**0.0006**
Cabbage	1233	120	125	**0.054**	10	**0.0043**	5	**0.0021**
Cucumber	385	60	125	**0.033**	10	**0.0027**	5	**0.0013**
Green bean	304	60	125	**0.026**	10	**0.0021**	5	**0.0011**

Broccoli	37	100	125	**0.002**	10	**0.0002**	5	**0.0001**
Eggplant	189	80	125	**0.012**	10	**0.0010**	5	**0.0005**
Green Collards	21	40	125	**0.003**	10	**0.0002**	5	**0.0001**
Spinach	159	30	125	**0.028**	10	**0.0022**	5	**0.0011**
Carrot	72	120	125	**0.003**	10	**0.0003**	5	**0.0001**
Red bean	112	90	125	**0.006**	10	**0.0005**	5	**0.0003**
Chayote	696	90	125	**0.040**	10	**0.0032**	5	**0.0016**
Fruits								
Orange	5625	250	32.5	**0.030**	3	**0.0028**	1.5	**0.0014**
Avocado	1985	210	32.5	**0.013**	3	**0.0012**	1.5	**0.0006**
Manggo	1055	120	32.5	**0.012**	3	**0.0011**	1.5	**0.0005**
Rambutan	300	150	32.5	**0.003**	3	**0.0003**	1.5	**0.0001**
Mangosteen	2315	110	32.5	**0.028**	3	**0.0026**	1.5	**0.0013**
Papaya	3117	365	32.5	**0.012**	3	**0.0011**	1.5	**0.0005**
Starfruit	270	120	32.5	**0.003**	3	**0.0003**	1.5	**0.0001**
Sapodilla	210	200	32.5	**0.001**	3	**0.0001**	1.5	**0.0001**
Banana	93077	90	32.5	**1.400**	3	**0.1293**	1.5	**0.0646**
Strawberry	20	14	32.5	**0.002**	3	**0.0002**	1.5	**0.0001**
Jack fruit	815	240	32.5	**0.005**	3	**0.0004**	1.5	**0.0002**
Cash Crop								
Coconut	411	365	32.5	**0.002**	3	**0.0001**	1.5	**0.0001**
Coffee	583	240	32.5	**0.003**	3	**0.0003**	1.5	**0.0002**
Tea	90.3	14	32.5	**0.009**	3	**0.0008**	1.5	**0.0004**
Clove	3586	120	32.5	**0.040**	3	**0.0037**	1.5	**0.0019**
Tobacco	8.0	120	32.5	**0.000**	3	**0.0000**	1.5	**0.0000**
Total	**125572**			**5.5225**		**0.5550**		**0.2775**

TABLE 52 PER CROP TYPE THE AREA, DAYS OF GROWING AND THE AVERAGE EMISSION IN THE CIRASEA AREA

Cirasea			*BOD*		*Nitrate*		*Sulphate*	
	Area (ha)	Time (hour)	Average emission (g/ha/plant season)	**Emission Estimation (kg/hour)**	Average emission (g/ha/plant season)	**Emission Estimation (kg/hour)**	Average emission (g/ha/plant season)	**Emission Estimation (kg/hour)**
WET FIELDS								
Paddy	29514	2880	225	**2.306**	20	**0.2050**	10	**0.1025**
water spinach	13	720	225	**0.004**	20	**0.0004**	10	**0.0002**
DRY FIELDS								
Paddy	2231	2880	225	**0.174**	20	**0.0155**	10	**0.0077**
Corn	13413	2400	125	**0.699**	10	**0.0559**	5	**0.0279**
Soya bean	516	2160	125	**0.030**	10	**0.0024**	5	**0.0012**
Peanuts	489	2400	125	**0.025**	10	**0.0020**	5	**0.0010**
Long beans	95	2400	125	**0.005**	10	**0.0004**	5	**0.0002**
Cassava	1972	6480	125	**0.038**	10	**0.0030**	5	**0.0015**
Sweet potato/ yam	1248	2880	125	**0.054**	10	**0.0043**	5	**0.0022**
Vegetables								
Chili	1072	1560	125	**0.086**	10	**0.0069**	5	**0.0034**
Garlic	1	2400	125	**0.000**	10	**0.0000**	5	**0.0000**
Red Onion/ Shallot	462	1920	125	**0.030**	10	**0.0024**	5	**0.0012**
Chive	1175	2160	125	**0.068**	10	**0.0054**	5	**0.0027**
Tomato	982	1560	125	**0.079**	10	**0.0063**	5	**0.0031**
Collards/ chicory	456	1680	125	**0.034**	10	**0.0027**	5	**0.0014**
Potato	1581	2880	125	**0.069**	10	**0.0055**	5	**0.0027**
Cabbage	1453	2880	125	**0.063**	10	**0.0050**	5	**0.0025**
Cucumber	96	1440	125	**0.008**	10	**0.0007**	5	**0.0003**
Green bean	221	1440	125	**0.019**	10	**0.0015**	5	**0.0008**
Broccoli	4	2400	125	**0.000**	10	**0.0000**	5	**0.0000**
Eggplant	48	1920	125	**0.003**	10	**0.0003**	5	**0.0001**
Green Collards	4.43	960	125	**0.001**	10	**0.0000**	5	**0.0000**
Spinach	12	720	125	**0.002**	10	**0.0002**	5	**0.0001**
Carrot	187	2880	125	**0.008**	10	**0.0006**	5	**0.0003**
Red bean	467	2160	125	**0.027**	10	**0.0022**	5	**0.0011**

Chayote	62	2160	125	**0.004**	10	**0.0003**	5	**0.0001**
Fruits								
Orange	0.4	6000	32.5	**0.000**	3	**0.0000**	1.5	**0.0000**
Avocado	26	5040	32.5	**0.000**	3	**0.0000**	1.5	**0.0000**
Manggo	27	2880	32.5	**0.000**	3	**0.0000**	1.5	**0.0000**
Papaya	4	8760	32.5	**0.000**	3	**0.0000**	1.5	**0.0000**
Starfruit	1	2880	32.5	**0.000**	3	**0.0000**	1.5	**0.0000**
Banana	232	2160	32.5	**0.003**	3	**0.0003**	1.5	**0.0002**
Jack fruit	1.62	5760	32.5	**0.000**	3	**0.0000**	1.5	**0.0000**
Cash Crop								
Coconut	73.68	8760	32.5	**0.000**	3	**0.0000**	1.5	**0.0000**
Coffee	1920.25	5760	32.5	**0.011**	3	**0.0010**	1.5	**0.0005**
Tea	6181	336	32.5	**0.598**	3	**0.0552**	1.5	**0.0276**
Clove	42.63	2880	32.5	**0.000**	3	**0.0000**	1.5	**0.0000**
Rubber	18	4320	32.5	**0.000**	3	**0.0000**	1.5	**0.0000**
Tobacco	1119	2880	32.5	**0.013**	3	**0.0012**	1.5	**0.0006**
Total	67425			**4.5**		**0.4**		**0.2**

TABLE 53 PER CROP TYPE THE AREA, DAYS OF GROWING AND THE AVERAGE EMISSION IN THE CISANGKUY AREA

Cisangkuy			***BOD***		***Nitrate***		***Sulphate***	
	Area (ha)	Time (hour)	Average emission (g/ha/plant season)	**Emission Estimation (kg/hour)**	Average emission (g/ha/plant season)	**Emission Estimation (kg/hour)**	Average emission (g/ha/plant season)	**Emission Estimation (kg/hour)**
WET FIELDS								
Paddy	12327	2880	225	**0.96**	20	**0.09**	10	**0.04**
water spinach	21	720	225	**0.01**	20	**0.0006**	10	**0.0003**
DRY FIELDS								
Paddy	459	2880	225	**0.04**	20	**0.003**	10	**0.002**
Corn	2884	2400	125	**0.15**	10	**0.01**	5	**0.006**
Soya bean	1	2160	125	**0.00**	10	**5.44E-06**	5	**2.72E-06**
Peanuts	84	2400	125	**0.00**	10	**0.0004**	5	**0.0002**
Long beans	43	2400	125	**0.002**	10	**0.0002**	5	**9.01E-05**
Cassava	516	6480	125	**0.01**	10	**0.0008**	5	**0.0004**

Sweet potato/ yam	995	2880	125	**0.04**	10	**0.003**	5	**0.002**
Vegetables								
Chili	7432	1560	125	**0.60**	10	**0.05**	5	**0.02**
Red Onion/ Shallot	1923	1920	125	**0.13**	10	**0.01**	5	**0.005**
Chive	65	2160	125	**0.004**	10	**0.0003**	5	**0.0002**
Tomato	1624	1560	125	**0.13**	10	**0.01**	5	**0.005**
Collards/ chicory	1262	1680	125	**0.09**	10	**0.008**	5	**0.004**
Potato	16422	2880	125	**0.71**	10	**0.06**	5	**0.03**
Cabbage	13030	2880	125	**0.57**	10	**0.05**	5	**0.02**
Cucumber	84	1440	125	**0.01**	10	**0.0006**	5	**0.0003**
Green bean	240	1440	125	**0.02**	10	**0.0017**	5	**0.0008**
Broccoli	27	2400	125	**0.001**	10	**0.0001**	5	**5.68E-05**
Eggplant	18	1920	125	**0.001**	10	**9.616E-05**	5	**4.81E-05**
Green Collards	621	960	125	**0.08**	10	**0.006**	5	**0.003**
Spinach	3	720	125	**0.0004**	10	**3.534E-05**	5	**1.77E-05**
Carrot	1123	2880	125	**0.05**	10	**0.004**	5	**0.002**
Chayote	1438	2160	125	**0.08**	10	**0.007**	5	**0.003**
Fruits								
Orange	115	6000	32.5	**0.00062**	3	**0.00006**	1.5	**2.88E-05**
Avocado	107	5040	32.5	**0.00069**	3	**6.339E-05**	1.5	**3.17E-05**
Manggo	6	2880	32.5	**0.00007**	3	**6.25E-06**	1.5	**3.13E-06**
Papaya	5	8760	32.5	**0.00002**	3	**1.541E-06**	1.5	**7.71E-07**
Starfruit	2	2880	32.5	**0.00002**	3	**1.563E-06**	1.5	**7.81E-07**
Banana	446	2160	32.5	**0.00671**	3	**0.0006**	1.5	**0.0003**
Cash Crop								
Coconut	20	8760	32.5	**0.00**	3	**6.747E-06**	1.5	**3.37E-06**
Coffee	1502	5760	32.5	**0.01**	3	**0.0008**	1.5	**0.000391**
Tea	6672	336	32.5	**0.65**	3	**0.06**	1.5	**0.029786**
Clove	14	2880	32.5	**0.00**	3	**1.442E-05**	1.5	**7.21E-06**
Rubber	4	4320	32.5	**0.00**	3	**2.778E-06**	1.5	**1.39E-06**
Tobacco	7	2880	32.5	**0.00**	3	**6.771E-06**	1.5	**3.39E-06**
Total	71542			**4.4**		**0.4**		**0.2**

TABLE 54 PER CROP TYPE THE AREA, DAYS OF GROWING AND THE AVERAGE EMISSION IN THE CITARIK AREA

Citarik			***BOD***		***Nitrate***		***Sulphate***	
	Area (ha)	Time (hour)	Average emission (g/ha/plant season)	**Emission Estimation (kg/hour)**	Average emission (g/ha/plant season)	**Emission Estimation (kg/hour)**	Average emission (g/ha/plant season)	**Emission Estimation (kg/hour)**
WET FIELDS								
Paddy	30563	2880	225	**2.4**	20	**0.2**	10	**0.1**
water spinach	558	720	225	**0.2**	20	**0.02**	10	**0.008**
DRY FIELDS								
Paddy	1979	2880	225	**0.2**	20	**0.01**	10	**0.01**
Corn	14380	2400	125	**0.7**	10	**0.06**	5	**0.03**
Soya bean	1295	2160	125	**0.07**	10	**0.01**	5	**0.003**
Peanuts	1639	2400	125	**0.09**	10	**0.007**	5	**0.003**
Long beans	23504	2400	125	**1.2**	10	**0.1**	5	**0.05**
Cassava	4754	6480	125	**0.09**	10	**0.007**	5	**0.004**
Sweet potato/ yam	1411	2880	125	**0.06**	10	**0.005**	5	**0.002**
Vegetables								
Chili	1759848	1560	125	**141.0**	10	**11.3**	5	**5.6**
Garlic	2800	2400	125	**0.1**	10	**0.01**	5	**0.006**
Red Onion/ Shallot	56347	1920	125	**3.7**	10	**0.3**	5	**0.1**
Chive	13413	2160	125	**0.8**	10	**0.06**	5	**0.03**
Tomato	447212	1560	125	**35.8**	10	**2.9**	5	**1.4**
Collards/ chicory	201462	1680	125	**15.0**	10	**1.2**	5	**0.6**
Potato	26297	2880	125	**1.1**	10	**0.1**	5	**0.05**
Cabbage	173328	2880	125	**7.5**	10	**0.6**	5	**0.3**
Cucumber	107252	1440	125	**9.3**	10	**0.7**	5	**0.4**
Green bean	29738	1440	125	**2.6**	10	**0.2**	5	**0.1**
Broccoli	42401	2400	125	**2.2**	10	**0.2**	5	**0.09**
Eggplant	22150	1920	125	**1.4**	10	**0.1**	5	**0.06**
Spinach	35	720	125	**0.006**	10	**0.0005**	5	**0.0002**
Carrot	4555	2880	125	**0.2**	10	**0.02**	5	**0.008**
Red bean	800477	2160	125	**46.3**	10	**3.7**	5	**1.9**
Chayote	201	2160	125	**0.01**	10	**0.0009**	5	**0.0005**

Cash Crop								
Coconut	1031	8760	32.5	**0.004**	3	**0.0004**	1.5	**0.0002**
Coffee	738	5760	32.5	**0.004**	3	**0.0004**	1.5	**0.0002**
Tea	525	336	32.5	**0.05**	3	**0.005**	1.5	**0.002**
Clove	742	2880	32.5	**0.008**	3	**0.0008**	1.5	**0.0004**
Rubber	4	4320	32.5	**3E-05**	3	**2.98E-06**	1.5	**1.49E-06**
Tobacco	1337	2880	32.5	**0.02**	3	**0.001**	1.5	**0.0007**
Total	**3771977**			**272.3**		**21.8**		**10.9**

TABLE 55 PER CROP TYPE THE AREA, DAYS OF GROWING AND THE AVERAGE EMISSION IN THE CIWIDEY AREA

Ciwidey			***BOD***		***Nitrate***		***Sulphate***	
	Area (ha)	Time (hour)	Average emission (g/ha/plant season)	**Emission Estimation (kg/hour)**	Average emission (g/ha/plant season)	**Emission Estimation (kg/hour)**	Average emission (g/ha/ plant season)	**Emission Estimation (kg/hour)**
WET FIELDS								
Paddy	11426	2880	225	**0.9**	20	**0.08**	10	**0.04**
DRY FIELDS								
Paddy	40	2880	225	**0.003**	20	**0.0003**	10	**0.0001**
Corn	364	2400	125	**0.02**	10	**0.002**	5	**0.0008**
Peanuts	12	2400	125	**0.0006**	10	**0.00005**	5	**2.5E-05**
Long beans	89	2400	125	**0.005**	10	**0.0004**	5	**0.0002**
Cassava	494	6480	125	**0.01**	10	**0.0008**	5	**0.0004**
Sweet potato/ yam	85	2880	125	**0.004**	10	**0.0003**	5	**0.0001**
Vegetables								
Chili	79	1560	125	**0.006**	10	**0.0005**	5	**0.0003**
Garlic	1	2400	125	**5.9E-05**	10	**4.7E-06**	5	**2.4E-06**
Red Onion/ Shallot	42	1920	125	**0.003**	10	**0.0002**	5	**0.0001**
Chive	66	2160	125	**0.004**	10	**0.0003**	5	**0.0002**
Tomato	168	1560	125	**0.01**	10	**0.001**	5	**0.0005**
Collards/ chicory	64	1680	125	**0.005**	10	**0.0004**	5	**0.0002**
Potato	19	2880	125	**0.001**	10	**6.68E-05**	5	**3.34E-05**
Cabbage	272	2880	125	**0.01**	10	**0.001**	5	**0.0005**
Cucumber	199	1440	125	**0.02**	10	**0.001**	5	**0.0007**

Green bean	139	1440	125	**0.01**	10	**0.001**	5	**0.0005**
Broccoli	8	2400	125	**0.0004**	10	**3.2E-05**	5	**1.62E-05**
Eggplant	25	1920	125	**0.002**	10	**0.0001**	5	**6.42E-05**
Green Collards	1620	960	125	**0.2**	10	**0.02**	5	**0.008**
Carrot	1	2880	125	**4.3E-05**	10	**3.5E-06**	5	**1.74E-06**
Red bean	7	2160	125	**0.0004**	10	**3.4E-05**	5	**1.69E-05**
Fruits								
Orange	3	6000	32.5	**1.5E-05**	3	**1.4E-06**	1.5	**6.8E-07**
Avocado	954	5040	32.5	**0.006**	3	**0.0006**	1.5	**0.0003**
Sapodilla	169	4800	32.5	**0.001**	3	**0.0001**	1.5	**5.28E-05**
Strawberry	246	336	32.5	**0.02**	3	**0.002**	1.5	**0.001**
Cash Crop								
Coffee	738	5760	32.5	**0.004**	3	**0.0004**	1.5	**0.0002**
Tea	163	336	32.5	**0.02**	3	**0.001**	1.5	**0.0007**
Clove	1	2880	32.5	**6.7E-06**	3	**6.1E-07**	1.5	**3.07E-07**
Total	**17491**			**1.3**		**0.1**		**0.06**

C.2 Estimated emission stockbreeding

TABLE 56 THE NUMBER OF ANIMALS AND THE EMISSION PER ANIMAL FOR THE CIKAPUNDUNG AREA

Cikapundung		*BOD*		*Nitrate*		*Sulphate*		*COD*		*Fecal (x1000)*	
	Number of Animal (x1000)	(mg/animal /day)	(kg/h)	(mg/animal /day)	(kg/h)	(mg/animal /day)	(kg/h)	(mg/animal /day)	(kg/h)	(coliform/animal /day)	(kg/h)
Dairy Cows	27.9	87400	**101.8**	28120	**32.8**	3115	**3.6**	262200	**305.4**	2900	3377.9
Beef Cows	18.2	100380	**76.1**	27720	**21.0**	6890	**5.2**	319200	**242.1**	3200	2426.7
Buffalo	2.6	110000	**12.0**	60225	**6.6**	3520	**0.4**	302500	**33.0**	4400	479.8
Horse	3.2	58125	**7.9**	14500	**2.0**	2150	**0.3**	156250	**21.1**	2000	270.5
Goat	27	21100	**23.7**	26200	**29.5**	725	**0.8**	59000	**66.4**	1000	1125.1
Sheep	293	22500	**274.3**	10800	**131.6**	1098	**13.4**	77355	**942.9**	860	10483.0
Free-running chicken	1215	1200	**60.8**	290	**14.7**	109	**5.5**	2620	**132.7**	12	607.7
Laying hens	116	1625	**7.8**	495	**2.4**	165	**0.8**	7100	**34.3**	12	58.0
Broiler chicken	13671	1570	**894.3**	445	**253.5**	120	**68.4**	5440	**3098.8**	12	6835.5
Duck	254	1420	**15.0**	395	**4.2**	163	**1.7**	5180	**54.8**	140	1480.6
Total			**1473.7**		**498.2**		**100.1**		**4931.4**		**27144.7**

TABLE 57 THE NUMBER OF ANIMALS AND THE EMISSION PER ANIMAL FOR THE CIRASEA AREA

Cirasea		*BOD*		*Nitrate*		*Sulphate*		*COD*		*Fecal (x1000)*	
	Number of Animal (x1000)	(mg/animal /day)	(kg/h)	(mg/animal /day)	(kg/h)	(mg/animal /day)	(kg/h)	(mg/animal /day)	(kg/h)	(coliform/animal /day)	(kg/h)
Dairy Cows	6.1	87400	**22.3**	28120	**7.2**	3115	**0.8**	262200	**67.0**	2900	741.0
Beef Cows	2.4	100380	**10.1**	27720	**2.8**	6890	**0.7**	319200	**32.0**	3200	320.7
Buffalo	1.6	110000	**7.6**	60225	**4.1**	3520	**0.2**	302500	**20.8**	4400	302.9
Horse	0.3	58125	**0.8**	14500	**0.2**	2150	**0.0**	156250	**2.1**	2000	26.8
Goat	77.7	21100	**6.8**	26200	**8.5**	725	**0.2**	59000	**19.1**	1000	323.2
Sheep	167	22500	**156.9**	10800	**75.3**	1098	**7.7**	77355	**539.3**	860	5996.0
Free-running chicken	373	1200	**18.7**	290	**4.5**	109	**1.7**	2620	**40.8**	12	186.7
Laying hens	164	1625	**11.1**	495	**3.4**	165	**1.1**	7100	**48.4**	12	81.8
Broiler chicken	9148	1570	**598.4**	445	**169.6**	120	**45.7**	5440	**2073.6**	12	4574.1
Duck	226	1420	**13.4**	395	**3.7**	163	**1.5**	5180	**48.7**	140	1316.8
Total			**846.0**		**279.3**		**59.7**		**2891.7**		

TABLE 58 THE NUMBER OF ANIMALS AND THE EMISSION PER ANIMAL FOR THE CISANGKUY AREA

Cisangkuy		***BOD***		***Nitrate***		***Sulphate***		***COD***		***Fecal (x1000)***	
	Number of Animal (x1000)	(mg/animal /day)	(kg/h)	(mg/animal /day)	(kg/h)	(mg/animal /day)	(kg/h)	(mg/animal /day)	(kg/h)	(coliform/animal /day)	(kg/h)
Dairy Cows	17	87400	**61.2**	28120	**19.7**	3115	**2.2**	262200	**183.7**	2900	2031.9
Beef Cows	1.5	100380	**6.4**	27720	**1.8**	6890	**0.4**	319200	**20.4**	3200	204.9
Buffalo	0.6	110000	**2.9**	60225	**1.6**	3520	**0.1**	302500	**7.9**	4400	114.8
Horse	0.2	58125	**0.5**	14500	**0.1**	2150	**0.0**	156250	**1.4**	2000	17.9
Goat	1.7	21100	**1.6**	26200	**1.9**	725	**0.1**	59000	**4.4**	1000	73.9
Sheep	54	22500	**50.7**	10800	**24.3**	1098	**2.5**	77355	**174.4**	860	1938.9
Free-running chicken	43	1200	**2.1**	290	**0.5**	109	**0.2**	2620	**4.7**	12	21.5
Laying hens	1.3	1625	**0.1**	495	**0.0**	165	**0.0**	7100	**0.4**	12	0.7
Broiler chicken	6361	1570	**416.1**	445	**117.9**	120	**31.8**	5440	**1441.8**	12	3180.4
Duck	96	1420	**5.7**	395	**1.6**	163	**0.7**	5180	**20.7**	140	558.8
Total			**547.4**		**169.5**		**37.9**		**1859.8**		**8143.7**

TABLE 59 THE NUMBER OF ANIMALS AND THE EMISSION PER ANIMAL FOR THE CITARIK AREA

Citarik		***BOD***		***Nitrate***		***Sulphate***		***COD***		***Fecal (x1000)***	
	Number of Animal (x1000)	(mg/animal /day)	(kg/h)	(mg/animal /day)	(kg/h)	(mg/animal /day)	(kg/h)	(mg/animal /day)	(kg/h)	(coliform/anima l/day)	(kg/h)
Dairy Cows	5.6	87400	**20.4**	28120	**6.6**	3115	**0.7**	262200	**61.2**	2900	677.2
Beef Cows	11.2	100380	**46.8**	27720	**12.9**	6890	**3.2**	319200	**149.0**	3200	1493.5
Buffalo	1.5	110000	**6.9**	60225	**3.8**	3520	**0.2**	302500	**18.9**	4400	275.6
Horse	0.5	58125	**1.1**	14500	**0.3**	2150	**0.0**	156250	**3.0**	2000	38.6
Goat	11.2	21100	**9.8**	26200	**12.2**	725	**0.3**	59000	**27.4**	1000	465.0
Sheep	135	22500	**126.5**	10800	**60.7**	1098	**6.2**	77355	**434.8**	860	4833.4
Free-running chicken	244	1200	**12.2**	290	**3.0**	109	**1.1**	2620	**26.7**	12	122.1
Laying hens	53	1625	**3.6**	495	**1.1**	165	**0.4**	7100	**15.6**	12	26.3
Broiler chicken	5392	1570	**352.7**	445	**100.0**	120	**27.0**	5440	**1222.2**	12	2696.0
Duck	133	1420	**7.9**	395	**2.2**	163	**0.9**	5180	**28.8**	140	777.5
Total			**587.9**		**202.6**		**40.0**		**1987.5**		**11405.1**

TABLE 60 THE NUMBER OF ANIMALS AND THE EMISSION PER ANIMAL FOR THE CIKAPUNDUNG AREA

Ciwidey		***BOD***		***Nitrate***		***Sulphate***		***COD***		***Fecal (x1000)***	
	Number of Animal (x1000)	(mg/animal /day)	(kg/h)	(mg/animal /day)	(kg/h)	(mg/animal /day)	(kg/h)	(mg/animal /day)	(kg/h)	(coliform/animal /day)	(kg/h)
Dairy Cows	4.4	87400	**16.0**	28120	**5.1**	3115	**0.6**	262200	**47.9**	2900	530.0
Beef Cows	1.2	100380	**4.9**	27720	**1.3**	6890	**0.3**	319200	**15.5**	3200	155.3
Buffalo	0.3	110000	**1.3**	60225	**0.7**	3520	**0.04**	302500	**3.7**	4400	53.5
Horse	0.2	58125	**0.5**	14500	**0.1**	2150	**0.02**	156250	**1.3**	2000	16.6
Goat	2.7	21100	**2.4**	26200	**3.0**	725	**0.08**	59000	**6.7**	1000	113.4
Sheep	17.3	22500	**16.2**	10800	**7.8**	1098	**0.8**	77355	**55.8**	860	620.6
Free-running chicken	48	1200	**2.4**	290	**0.6**	109	**0.2**	2620	**5.2**	12	24.0
Laying hens	0.8	1625	**0.1**	495	**0.0**	165	**0.01**	7100	**0.2**	12	0.4
Broiler chicken	10531	1570	**688.9**	445	**195.3**	120	**52.7**	5440	**2387.0**	12	5265.4
Duck	25	1420	**1.5**	395	**0.4**	163	**0.2**	5180	**5.4**	140	145.0
Total			**734.1**		**214.4**		**54.9**		**2528.7**		**6924.3**

APPENDIX D: EMISSION OF INDUSTRIES

D.1. Loads from industries in the original situation

In this table the loads from the different types of industries per sub basin are given. It shows that textile is the biggest polluter and that nitrate, fecal coliform and sulphate are hardly emitted by industries.

TABLE 61 LOADS FROM DIFFERENT INDUSTRIES PER SUB BASIN

		BOD	*COD*	*Nitrate*	*Coliform*	*Sulfate*	*Zinc*
Cikapundung	Textile	204.1	562.7	0.0	0	0	0
	Paint	0.1	0.2	0.0	0	0	0
	leather	0.0	0.0	0.0	0	0	0
	Pharmacy	15.5	26.7	0.0	0	0	0
	Paper	1.1	4.9	0.0	0	0	0
	Chemistry	0.1	0.3	0.1	0	0	0.0007
	Metal	0.0	0.0	0.0	0	0	0.0081
	Food	4.1	10.8	0.4	0	0	0.0062
	Other	1.7	4.5	0.0	0	0	0.0000
	Total	226.5	610.1	0.5	0	0	0.0150
Citarik	Textile	169.5	459.1	0.0	0	0	0.0000
	Paint	0.0	0.1	0.0	0	0	0.0000
	leather	0.0	0.0	0.0	0	0	0.0000
	Pharmacy	0.2	0.3	0.0	0	0	0.0000
	Paper	0.9	4.1	0.0	0	0	0.0000
	Chemistry	0.1	0.4	0.1	0	0	0.0009
	Metal	0.0	0.0	0.0	0	0	0.0007
	Food	0.5	1.3	0.0	0	0	0.0007
	Other	3.3	8.9	0.0	0	0	0.0000
	Total	174.4	474.0	0.2	0	0	0.0023
Cirasea	Textile	187.5	501.4	0.0	0	0	0.0000
	Total	187.5	501.4	0.0	0	0	0.0000
Cisangkuy	Textile	134.1	365.1	0.0	0	0	0.0000
	Geothermal	1.0	2.8	0.0	0	0	0.0000
	Pharmacy	0.0	0.0	0.0	0	0	0.0000
	Paper	118.8	241.0	0.0	0	0	0.0000
	Chemistry	0.4	1.8	0.5	0	0	0.0044
	Metal	0.0	0.0	0.0	0	0	0.0000
	Food	1.2	3.0	0.1	0	0	0.0018
	Tea plantation	0.3	1.0	0.0	0	0	0.0000
	Other	39.2	107.3	0.0	0	0	0.0000
	Total	295.0	722.0	0.6	0	0	0.0062
Ciwidey	Textile	54.7	181.4	0.0	0	0	0
	Chemistry	0.0	0.0	0.0	0	0	0.00005
	Tea plantation	0.0	0.0	0.0	0	0	0
	Total	54.7	181.4	0.0	0	0	0.00005

D.2. Loads from industries without textile industries

TABLE 62 LOADS FROM DIFFERENT INDUSTRIES PER SUB BASIN WITHOUT TEXTILE INDUSTRY

(kg/h)		*BOD*	*COD*	*Nitrate*	*Coliform*	*Sulfate*	*Zinc*
Cikapundung	Textile	0	0	0	0	0	0
	Paint	0.1	0.2	0	0	0	0
	Pharmacy	15.5	26.7	0	0	0	0
	Paper	1.1	4.9	0	0	0	0
	Chemistry	0.1	0.3	0.1	0	0	0.0007
	Metal	0.0	0.0	0	0	0	0.0081
	Food	4.1	10.8	0.4	0	0	0.0062
	Other	1.7	4.5	0	0	0	0
	Total	22.5	47.4	0.5	0	0	0.0150
Citarik	Textile	0	0	0	0	0	0
	Paint	0	0.1	0	0	0	0
	Pharmacy	0.2	0.3	0	0	0	0
	Paper	0.9	4.1	0	0	0	0
	Chemistry	0.1	0.4	0.1	0	0	0.0009
	Metal	0.0	0.0	0	0	0	0.0007
	Food	0.5	1.3	0	0	0	0.0007
	Other	3.3	8.9	0	0	0	0
	Total	4.9	15.0	0.2	0	0	0.0023
Cirasea	Textile	0	0	0	0	0	0
	Total	0	0	0	0	0	0
Cisangkuy	Textile	0	0	0	0	0	0
	Geothermal	1.0	2.8	0	0	0	0
	Pharmacy	0.0	0.0	0	0	0	0
	Paper	118.8	241.0	0	0	0	0
	Chemistry	0.4	1.8	0.5	0	0	0.0044
	Metal	0.0	0.0	0	0	0	0
	Food	1.2	3.0	0.1	0	0	0.0018
	Tea plantation	0.3	1.0	0	0	0	0
	Other	39.2	107.3	0	0	0	0
	Total	160.8	357.0	0.6	0	0	0.0062
Ciwidey	Textile	0	0	0	0	0	0
	Chemistry	0.004	0.02	0	0	0	0.00005
	Tea plantation	0.005	0.01	0	0	0	0
	Total	0.009	0.03	0	0	0	0.00005

In this table the textile factories are eliminated from the area. Therefore all the loads coming from textile is set to zero.

D.3. Loads from industries with textile factories changed into other

TABLE 63 LOADS FROM DIFFERENT INDUSTRIES PER SUB BASIN WITH TEXTILE FACTORIES CHANGED INTO OTHER INDUSTRIES

(kg/h)		*BOD*	*COD*	*Nitrate*	*Coliform*	*Sulfate*	*Zinc*
Cikapundung	Textile	0	0	0	0	0	0
	Paint	0.1	0.2	0	0	0	0
	Pharmacy	18.2	32.5	0	0	0	0
	Paper	1.1	5.1	0	0	0	0
	Chemistry	0.1	0.3	0.1	0	0	0.0007
	Metal	0.0	0.0	0	0	0	0.01
	Food	4.7	12.4	0.5	0	0	0.007
	Other	2.0	5.5	0	0	0	0
	Total	26.2	55.0	0.6	0	0	0.02
Citarik	Textile	0	0	0	0	0	0
	Paint	0.03	0.08	0	0	0	0
	Pharmacy	0.2	0.3	0	0	0	0
	Paper	1.0	4.2	0	0	0	0
	Chemistry	0.1	0.4	0.1	0	0	0.001
	Metal	0	0	0	0	0	0.0008
	Food	0.5	1.5	0.06	0	0	0.0008
	Other	4.0	10.9	0	0	0	0
	Total	5.7	17.3	0.2	0	0	0.003
Cirasea	Textile	0	0	0	0	0	0
	Total	0	0	0	0	0	0
Cisangkuy	Textile	0	0	0	0	0	0
	Geothermal	1.1	3.0	0	0	0	0
	Pharmacy	0.003	0.006	0	0	0	0
	Paper	123.2	250.0	0	0	0	0
	Chemistry	0.4	2.0	0.6	0	0	0.005
	Metal	0.0	0.0	0	0	0	0
	Food	1.4	3.4	0.1	0	0	0.002
	Tea plantation	0.3	1.0	0	0	0	0
	Other	47.6	130.3	0	0	0	0
	Total	174.0	389.8	0.7	0	0	0.007
Ciwidey	Textile	0	0	0	0	0	0
	Chemistry	0.005	0.02	0.006	0	0	0.00005
	Tea plantation	0.005	0.01	0	0	0	0
	Total	0.01	0.03	0	0	0	0.00005

In this table the textile factories are converted into factories of one of the other industries. This is done by amount of occurrence. The largest industry after textile gets the most new factories.

APPENDIX E: EMISSION ESTIMATION UNREGISTERED INDUSTRY

To estimate the pollutant load from unregistered industries, facility information (number of employee, output of the product, and use of water) from several stakeholders (statistical and industrial agency) is used. However, since they are un-registered, very limited information is available on this kind of industries. The data available is based on the different districts in the area and not like the registered industry per catchment (Figure 26).

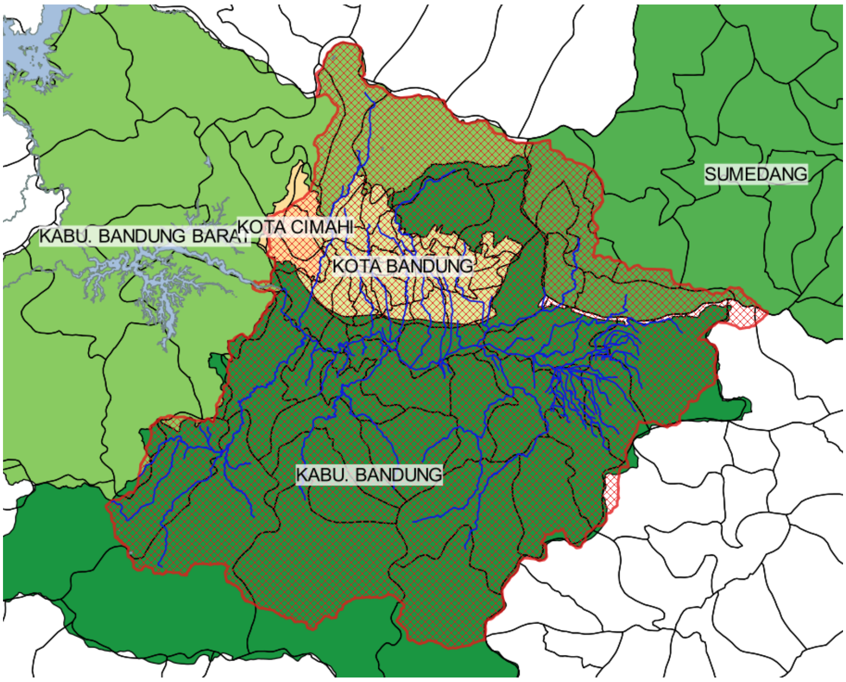


FIGURE 26 DIFFERENT DISTRICTS IN THE UPPER CITARUM BASIN. THE BASIN IS INDICATED BY SHADING. THE BLACK LINES INDICATE THE REGENCIES

With the data which is available the next steps can be taken to come to estimated pollutant load for the unregistered industry:

a) Number of population in each districts as basis data for calculation
b) Multiply number of population from each district by percentage of workers in each city and regency to get the number of employees in each district
c) Multiply the number of employees in each district by the percentage of how many people work in the industrial sector to get the number of industrial employees in each district
d) Multiply the number of industrial employees in each district by the percentage of micro and small industry to get the number of micro and small industrial employees in each district
e) Multiply the number of micro and small industrial employees in each district with the percentage of each type of industry from provincial data to get the number of micro and small industrial employee in each district per type of industry

f) Multiply the number of micro and small industrial employees in each district per type of industry by pollutants load unit to get the loads from unregistered industries in each district. This pollutant load unit is based on the Industrial Pollutant Prediction System of the World Bank (Martin & Wheeler, 1995)

TABLE 64 CALCULATING THE LOADS FOR SMALL AND MICRO INDUSTRY (STATISTICAL OFFICE OF INDONESIA)

	No of Population (District)	*No of total employee*	*Employee in industrial sector*	*Employee in micro and small industries*	*Employee per industrial sector in micro and small*	*Emission*
	(a)	(b)	(c)	(d)	(e)	(f)
Kab Bandung		(a)×41%	(b)×37%			
Kota Bandung		(a) ×41%	(b)×25%			(e)×see table 12
Kota Cimahi		(a) ×36%	(b)×29%	(c)×43%	(d)× see Table	Use Pollution Load Units (PLU)
Kab Bandung Barat		(a) ×50%	(b)×12%			
Kab Sumedang		(a) ×30%	(b)×12%			

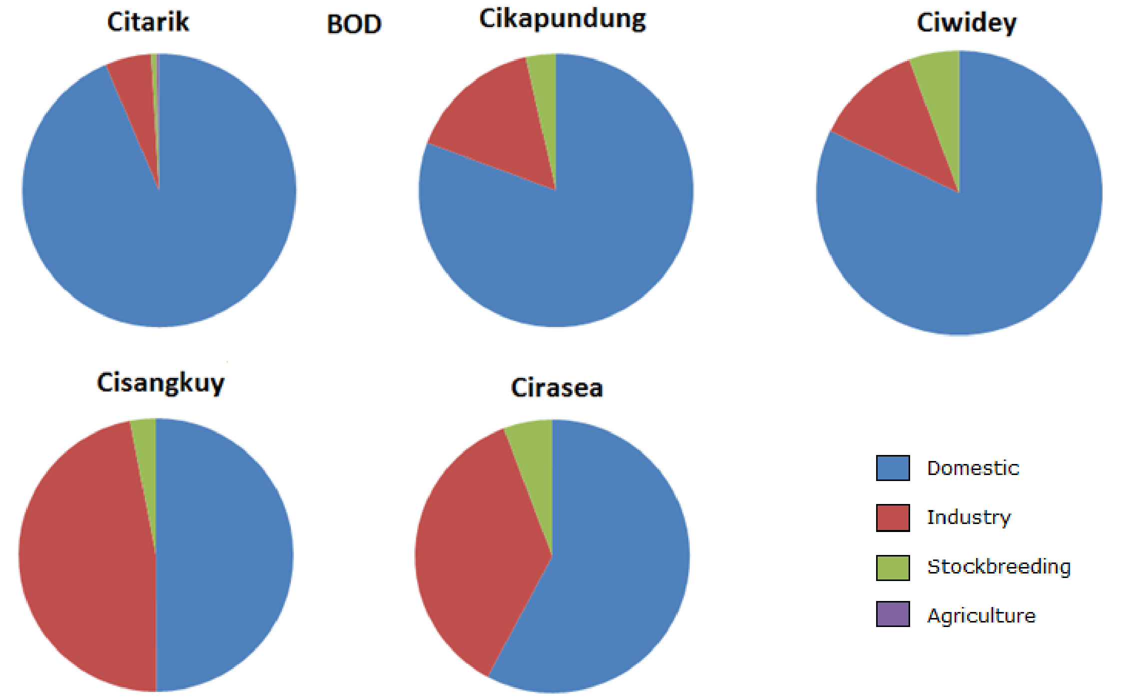
TABLE 65 PERCENTAGES OF WORKERS IN THE DIFFERENT INDUSTRIAL SECTORS (STATISTICAL OFFICE OF INDONESIA)

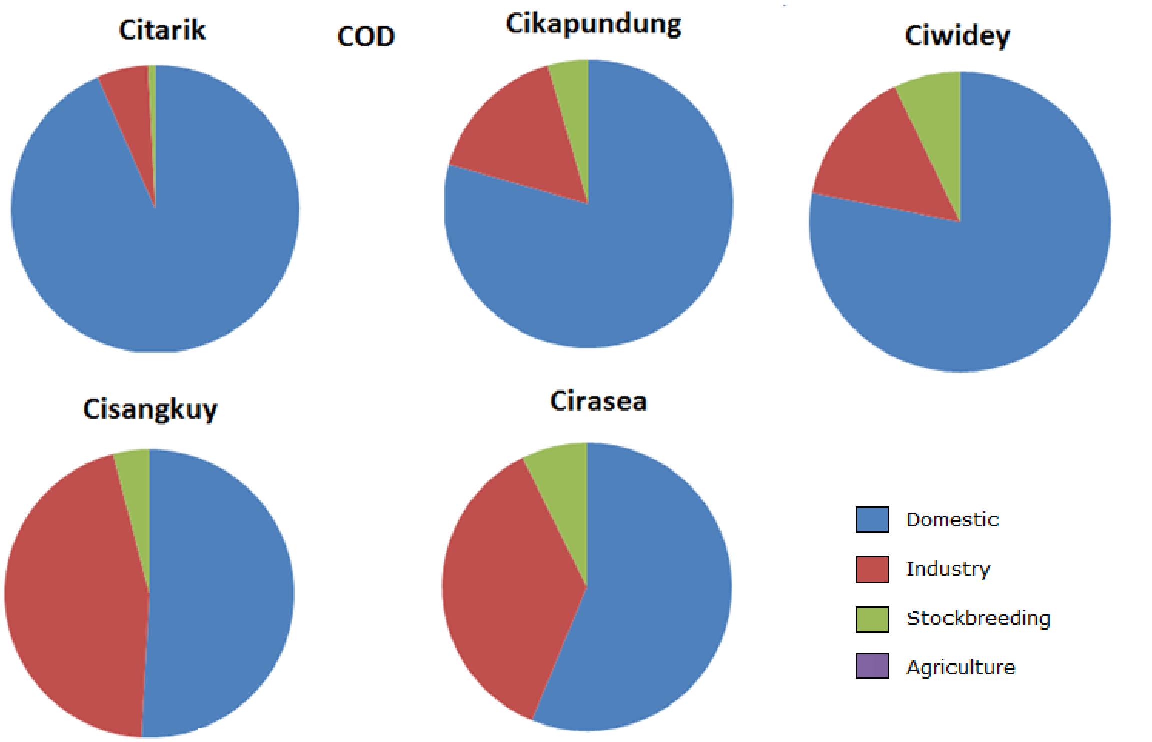
	% from total employees
Textile	19,71
Clothes	19,67
Food & beverages	9,23
Leather	4,26
Paper	2,25
Chemical	2,60
Pharmacy	1,46
Basic metal	3,45

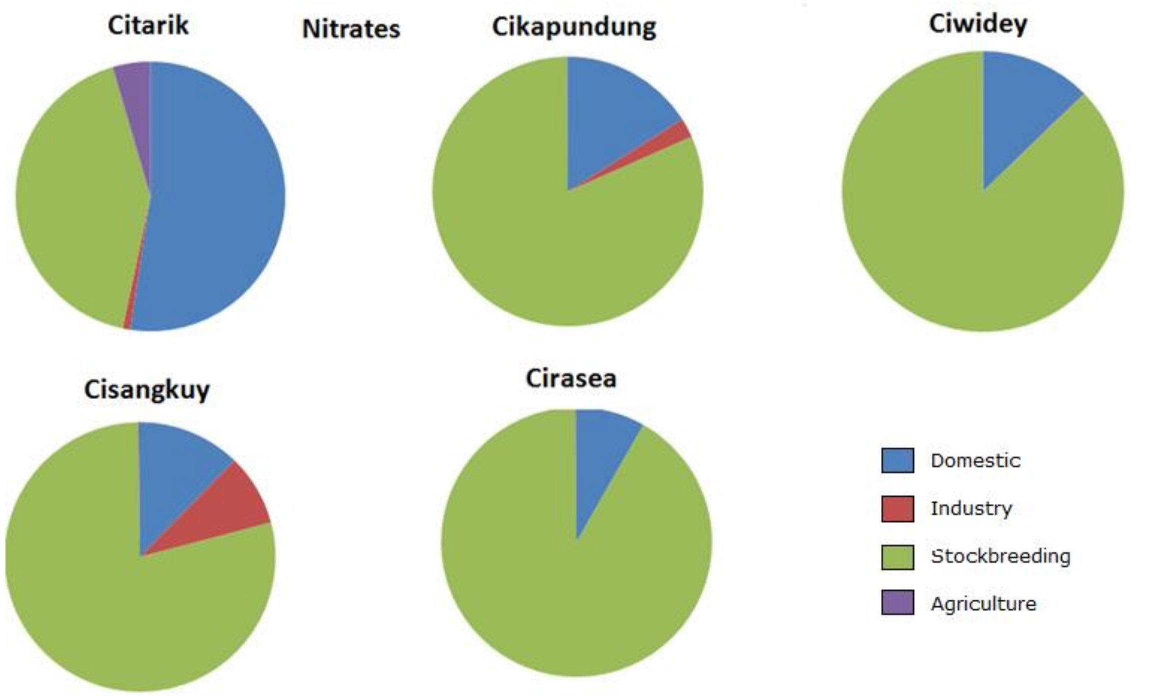
TABLE 66 INDUSTRIAL POLLUTANT PREDICTION SYSTEM (IPPS) WHICH GIVES AN INDICATION OF POLLUTANT LOADS FOR DIFFERENT INDUSTRIES (Martin & Wheeler, 1995)

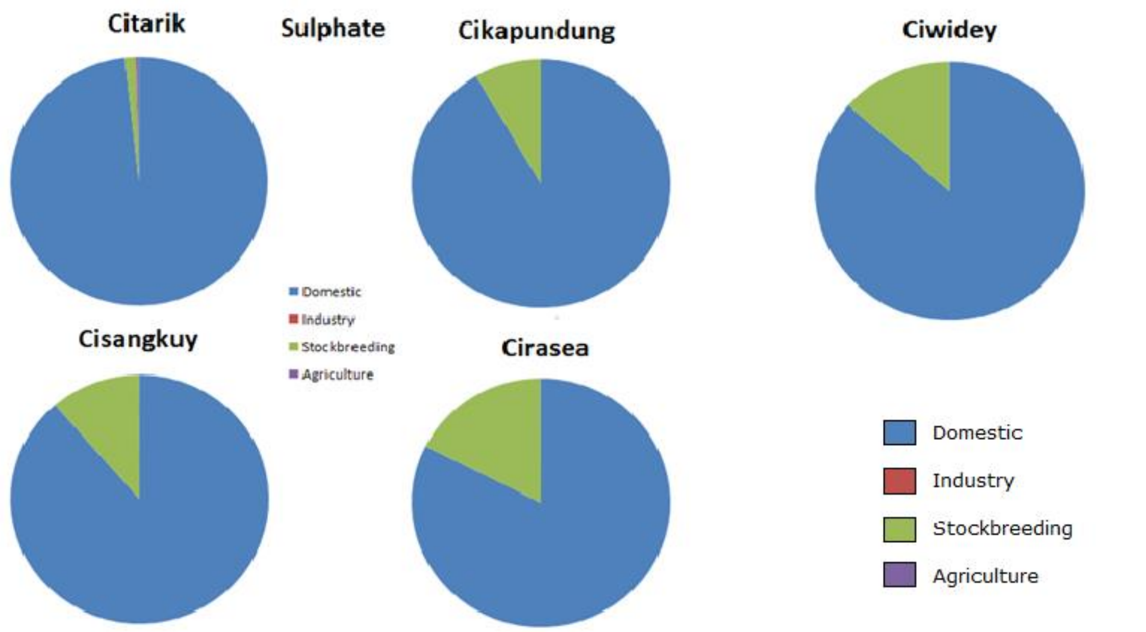
Four Digit ISIC Description	*ISIC Code*	*BOD Lower-Bound*	*BOD Inter-Quartile*
Food products	3121	274	
Spinning, weaving, & finishing textiles	3211	4172.6	21755.4
Tanneries and leather finishing	3231	43317.4	
Pulp, paper, & paperboard	3411	1497824.4	655217
Industrial chemicals	3511	5694612	5960.7
Drugs and medicines	3522	6433.4	2102.1
Structural metal products	3813	56.1	0
Manufacturing industries	3909	3.1	

APPENDIX F: RESULTS EMISSION ESTIMATION






Citarik
Nitrates
Cikapundung
Ciwidey
Cisangkuy
Cirasea
Domestic
Industry
Stockbreeding
Agriculture


Citarik
Sulphate
Cikapundung
Ciwidey
Domestic
Industry
Stockbreeding
Agriculture
Cisangkuy
Cirasea
Domestic
Industry
Stockbreeding
Agriculture