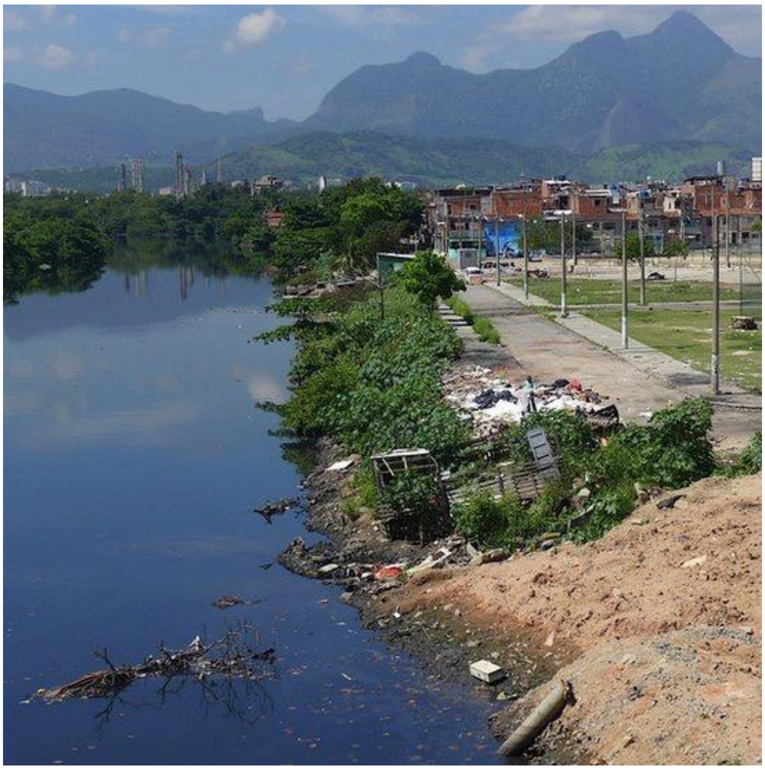
Student thesis series INES nr 355

Water quality in rivers affected by urbanization:
A Case Study in Minas Gerais, Brazil.



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2015
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Water quality in rivers affected by urbanization: A Case Study in Minas Gerais, Brazil.

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2015

Bachelor's thesis

in Physical Geography and Ecosystem analysis, Department of Physical Geography and Ecosystem science, Lund University

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Förord

Anledningen till varför jag valt att skriva min kandidatuppsats om frågor rörande urbanisering och dess koppling till vattenkvalitet är dels för att jag har ett stort intresse för vatten- och miljöskyddsfrågor och också för att jag tycker det är ett otroligt angeläget och viktigt ämne att belysa. Urbanisering har funnits i alla tider men är samtidigt ett begrepp som har förändrats starkt och ser idag annorlunda ut än det gjorde för bara några decennier sedan. Urbaniseringens villkor har förändrats i takt med många olika faktorer som t.ex. ny byggteknik, människors livsstandard och en allt mer global värld. Det är ett intressant ämne att forska på då vi långt ifrån känner till alla konsekvenser som en allt mer urbaniserad värld leder till. Förnödenheter som mat, bostäder och andra aspekter som livsstil och ekonomi har förändras för människor i dessa samhällen och trycket på omgivning och natur likaså. Urbaniseringen som sker i allt fler delar av världen, i allt snabbare takt, är en oundviklig och naturlig process då städer och länder utvecklas men det för samtidigt med sig en rad nya och svårhanterliga konsekvenser, inte minst på den lokala så väl som den globala miljön.

Jag har i denna studie intresserat mig för att undersöka vad som sker med vattnet i flodsystem, när en stad i relativt hög takt går från att vara ett mindre samhälle till att bli en starkt växande stad med statskärna och omgivning. Framförallt har jag valt att inrikta min studie på Brasilien där en stark ekonomisk utveckling sker i likhet med andra BRIC[1] ekonomier. Fler och fler städer i Brasilien har idag problem med ett för stort befolkningstryck, där framtiden är oviss vad det leder till. En konsekvens som är relativt uppenbar är att det bidrar till en belastning på omgivande miljö och ekosystem.

Hur och i vilken grad vattenkvalitet påverkas i dessa områden är idag inte helt känt. Kopplingen mellan vatten och växande samhällen är en komplex ekvation som kan vara svår att modellera samt förutse, det har jag inte minst märkt under min tid då jag arbetat med denna studie. Att allt fler människor på en allt mindre yta utgör en belastning på omgivande vattensystem är ett igenkännande faktum och detta är idag på många ställen vardag i Brasilien där sinande vattenkvalitet i sjöar och vattensystem är ett stort problem. Vad som en gång var oaser med florerande biodiversitet är numera vattensystem som är syrefattiga, smutsiga och ur balans. Avloppsvatten och sopor fyller dessa vattensystem idag och alternativa reningssystem fattas ofta.

Urbaniseringens framfart är ett otroligt viktigt ämne som bör centraliseras och belysas bättre, så att en förändring till det bättre kan ske där man t.ex. byter ut odlingstekniker, utbildar fler människor i ämnet, bygger säkra och bra flodskydd och förbättrar reningstekniker. Människors hälsa och bevarandet av biodiversitet och rena och fungerande flodsystem bör vara ett ämne som tar större plats i politik och samhälle i Brasilien än vad det gör idag. I och med min studie vill jag uppmärksamma ett av vår tids största dilemman – att bevara och skapa hållbara

[1] BRIC är det akronym som används för Brasilien, Ryssland, Indien och Kina, fyra snabbt tillväxande stormakter som anses vara i liknande ekonomisk situation.

vattensystem och miljöer samtidigt som allt fler människor och större samhällen utnyttjar dess resurser.

Abstract

This study highlights the key issues that urban river systems face due to urbanization. The city of Frutal (20˚01' 32.17"S 48˚56' 09.62" W) centered in the Brazilian state of Minas Gerais is under urban expansion today. The aim of this study was to compare two rivers in this area, the Frutal River, an urban located river, with the Bebedouro River, which is a rural river approximately 3 km west of Frutal city. The purpose was to test if the urban located Frutal River is of a lower water quality than the rural, Bebedouro River, as a consequence of their different degree of exposure to urban environments. The city of Frutal suffers in some parts from environmental degradation mainly due to the increased rate of people moving into the city. This study intended to execute a water quality analysis of superficial water from both rivers to later compare their differences using statistics.

Physical, biological and chemical variables including pH, dissolved oxygen (DO), temperature, flow rate, hardness, electric conductivity (EC), total dissolved solids (TDS), alkalinity, chlorophyll-a, fecal and total coliforms were measured in each river and later compared between the two rivers. Three different periods in three different seasons; March, July and September were selected to collect water quality variables from each river.

The result showed that Frutal River had poorer water quality. A significant ($P<0.05$) difference between the rivers in temperature, pH, DO, EC, total hardness, total alkalinity, fecal coliforms, total coliforms and TDS was detected and a significant ($P<0.05$) difference in variables between the three tested seasons were found in temperature, pH, total hardness, total alkalinity, total coliforms and DO. This is strongly suggested being a consequence of the urbanization taken place in the city of Frutal and the lack of consisting and efficient environmental control.

The conclusion is that the city of Frutal has to protect its rivers further and suggestions to reduce the pollutions in the Frutal River is presented in constructing a sewage treatment plant in the catchment and also to increase the Green Infrastructure within the area.

KEY WORDS

Urbanization in Brazil, Water quality in Rivers, Statistics

Sammanfattning

Staden Frutal, centrerad i den brasilianska delstaten Minas Gerais är idag under stark urbanisering och utveckling. Målet med denna studie var att ta reda på om den starka urbaniseringen har påverkat närliggande vattensystem och dess vattenkvalité. I studien har vattenkvalitén i floden Frutal, en flod liggandes centralt i staden Frutal, jämförts med vattenkvalitén i floden Bebedouro, en lantlig flod, 3 kilometer väst om staden Frutal.

Staden Frutal lider på många områden av miljöförstöring främst på grund av den snabba folkökning som skett under de senaste decennierna. En stor källa till föroreningarna har sin grund i avfall från hushållsavloppsvatten och industriverksamhet i området. Denna studie avser att bedöma skillnader i föroreningar mellan dessa två floder och dess koppling till urbaniseringen med hjälp av vattenkvalitébedömning.

Kemiska parametrar inklusive pH, löst syre, temperatur, flöde, vattenhårdhet, elektrisk konduktivitet, totalt mängd lösta ämnen, alkalinitet, klorofyll a, fekalier samt totala kolibakterier har mätts ifrån varje flod och senare jämförs dem emellan. Tre olika perioder i tre olika årstider; hösten (mars), vinter (juli), vår (september), valdes för att samla in dessa kemiska parametrar från varje flod.

Resultaten i studien visade att floden Frutal hade en signifikant ($P<0.05$) lägre vattenkvalitet i 9 av de elva parametrar som mättes: Löst syre, temperatur, pH, alkalinitet, elektrisk konduktivitet, vattenhårdhet, fekalier, totala kolibakterier samt totalt mängd lösta ämnen.

Detta föreslås bero på den okontrollerade urbaniseringen i staden Frutal och avsaknaden av bestående och effektiv rengöring och miljöövervakning. Förslag för att minska föroreningarna i området presenteras bland annat i form av konstruktion av ett reningsverk vid floden Frutal samt mer grön infrastruktur i området.

NYCKELORD

Urbaniseringen i Brasilien, vattenkvalité i flodsystem, statistik

Acknowledgement

I would like to thank the Universidade Federal de Minas Gerais and the Class of 2014 at the Geography department, for the gathering and sharing of the variables for the tested rivers. I also like to thank the University of Birmingham for introducing me to the subject and making my interest for it grow. Lastly, I like to thank my eminent coordinator Martin Berggren for all help, good advice and thoughts on my study.

Contents

1 Introduction

One hundred years ago, eight out of ten people lived on the rural country side (WHO 2010). Today the reality is something completely different. Since 2008, the majority of the world's population lives in or in close proximity to cities and this figure is expected to be two thirds in just 50 years from now (WHO/UNICEF 2014). Growing cities and urban communities create new possibilities for humans and countries but as these changes occur, poverty and many other problematic issues often increase (Uttara *et al*. 2012). The parts of the world with the highest share of population living in urban areas are today Latin America and the Caribbean (SIDA 2013). Every year millions of people are moving into the cities, attracted by the opportunities it bears and with hope of a better existence. In Latin America the unemployment rates are high and people end up in the slums that rapidly expand on the outskirts of the cities (IBGE 2008). This leads to an increased pressure on the environment as lack of clean water, sanitation and of a sustainable solution for waste management are associated outcomes.

Population growth and an increased industrialization combined with land development along river basins lead to an increased stress on rivers, giving rise to water pollution and environmental deterioration (Sumok *et al*. 2001). Water quality in streams, rivers, lakes and coastal waters may change when the surrounding areas and watersheds are modified by alternations in vegetation, sediment balance, fertilizer-usage and industrial expansion; factors drastically affected by urbanization (Turner *et al*. 1991). Further, studies have found correlations between land-use increase due to urbanization and a worsened water quality. For example, LeBlanc *et al*. (1997) and Sheyla *et al*. (2006) both showed that water temperature is increased by land-use intensification which can alter the water constituents and increase the abundance of bacteria and algae. Fisher *et al*. (2000) showed that increases in land-use affects the water quality in a range of different factors including pH, dissolved solids and bacteria such as different forms of coliform bacteria. Research over the past decade has indicated that electric conductivity and concentrations of other generally conservative solutes found in waterways all have a positive correlation with the increased usage of land areas (Interlandi *et al*. 2003).

Flow rate in rivers is another factor that has been showed to have an effect on water quality (Interlandi *et al*. 2003). If the flow rate in rivers change due to alternations in precipitation combined with other factors as altered river banks, it may have a range of negative effects such as problematic turbidity levels, increased concentrations of organic matter, high levels of bacteria, viruses and parasites (Interlandi *et al*. 2003). The pH, alkalinity and hardness of a river all correlate strongly with one another. This is due to them all being a part of the carbonate system which will negatively affect water quality and wild life if these variables are not at the correct levels (Chakoumakos *et al*. 1979). In more urban rivers, levels of nitrogen, phosphorus, sulfur and other non-metals have been shown to be higher and affect the water quality in these rivers (Sunyer *et al*. 1997). Abundance in nitrogen caused by increase in sewage or a highly exploited land area from both point-sources pollution[2] and other more diffuse sources of pollution causes problems such as eutrophication and an increased bacterial growth

[2] Point-source pollution is water pollution coming from a single point, such as a sewage-outflow pipe.

(Bowen *et al*. 2011). In Brazil, sewage is a major cause of water pollution as a result of a rapid and poorly planned infrastructure (Ferreira da Fonseca *et al*. 2007).

Even though several studies have examined the correlation between an increase in land use and environmental- and water degradation in developing countries, especially China, and also in many wealthier countries, mainly the US, there are fewer studies on the subject of urbanization's effect on water quality in smaller water systems in a subtropical/tropical climate similar to Brazil's south east parts. Brazil is one of the world's fastest urban developing countries and so it is of a particular interest to carry out studies here. The ecosystem in Brazil has one of the richest and most unique biota in the world and the species and wildlife here are essential for a functioning world. If this part of the world is mistreated the consequences are set to be many and severe with climate change and ecological loss.

Former studies on this subject have presented correlations between water quality and different variables that arise from urbanization and an increasing percentage of land usage. However, these studied water systems have often been mistreated for a longer period and the water courses are often larger compared with the rivers in this study. There need to be more studies concerning small river basins and their vulnerability in environmental "heavy pressure zones" due to urbanization. Especially in the subtropic- and tropic climates as these are very sensitive areas with the largest percentage of the world′s species (WWF 2013) and unique biota that influence larger areas of the world.

1.1. Water quality in rivers

When assessing the quality of a waterbody there are three major components to include: Its hydrology, chemistry and biology. A river is measured relative to its requirements and purpose which mostly relates to health of ecosystems, safety of human contact or/and drinking water. Different agencies help with the standardization off water bodies in political and scientific decisions. The standards are often because of this, different for different countries i.e. the thresholds between different classes of water quality is depending on the countries standards. Brazil has a slightly higher acceptable level for a few of the measured variables in this study compared to many other developed countries (CONAMA 2005/375 2005).

Different chemical components and other pollution can enter surface water from either natural or anthropogenic sources. These may derive from either point-sources as a natural spring or industrial outfall, or non-point sources (NPS) i.e. more diffuse pollution sources such as runoff from land. In most cases there is usual an impairment of contaminants, depending on circumstances. In all cases however, contamination from a chemical or physical attribute must be measured on a local basis. To tell if a river is polluted or not may be very difficult as water quality is a complex subject which is affected by multiple variables and natural water bodies will vary in response to environmental conditions.

However, there are variables that when measured can tell if and to what extent a waterbody is polluted i.e. which state the water is in. When focusing on the environmental quality of water, also called the ambient water quality, measurements are commonly made on-site as water exists in equilibrium with its surroundings. Typical variables to test are: temperature, color, pH, dissolved oxygen, total dissolved solids, electric conductivity, fecal coliforms, chlorophyll-a, alkalinity, total hardness and micro-nutrients. As mentioned in the introduction, different studies have showed correlations between these parameters and an intensified land use. These variables will often change as a result of alternations in land use and surrounding environments when urbanization increases. This is the main reason why these variables (Table 1) have been selected to measure the water quality in both test rivers to see if there is a difference between them as a possible effect of the increased land use and human activity i.e. urbanization around the city of Frutal.

Table 1. *Suggested physical, chemical and biological variables to test in ambient waters and how they may be connected to human activities and urbanization*.

Temperature (°C)	Temperature is an independent variable that will affect all of the other variables tested in this study, as seen below. Therefor its of particular interest to test different variables at different times of the year when the water temperature is different as a fluctuation in water quality will be occurring. Human activities may affect water temperature, including; discharge of industrial effluents, agriculture, urban development that alters the characteristics and path of storm water runoff and climate change. The water temperature is studied to be increased as a consequence of an increased land-use. (LeBlanc *et al*. 1997 and Sheyla *et al*. 2006).
pH	pH correlates strongly with water temperature and is often increased when a surrounding land-use intensification occurs (Fisher *et al*. 2000). pH is measuring how acid or basic the water is. Human factors that may influence and increase the pH are to mention a few, acid rain, which can be produced by coal burning or automobile engines. Another way urbanization can affect pH in rivers are by point source pollution, when industrial pollutants are dumped directly into the water but NPS may also have this effect. Finally, mining can expose rocks to rainwater which may produce acidic runoff (Chakoumakos *et al*. 1979)
Dissolved Oxygen (mg/l)	DO is essential for a healthy aquatic ecosystem and a high percentage of DO often correlates with a cleaner, healthier and less altered water. A waterbody can hold more oxygen within itself if the temperature is lower and the overall disturbance from micro-nutrients and organic material is relatively low. Factors that often increases due to urbanization.

Flow (m³/s)	The flow in a river system is a function of water volume and velocity. The water flow of a river is interesting to measure as it affects different variables of the river. It may affect how well a river can handle waste and contamination as a slow velocity and flow will be less good in handling pollution discharge than a more rapid moving water will (Interlandi *et al*. 2013).
Electric Conductivity (µS/cm)	EC is a measure of the total amount of solids within the water. This also correlates strongly with the water temperature, that if higher, will increase the EC. To measure conductivity is a good indicator of the salinity of a waterbody, as salt leads electricity. EC is there for directly related to the total dissolved solids of the water, which may be correlated with waste and other nutrients as micro-nutrients from farming activities but also from industries and urban activity (EPA 2012).
Total Dissolved Solids (ppm)	Total dissolved solids (TDS) is a measure of the organic and inorganic substances in water. It is related to electric conductivity as it also tells how much salt a waterbody contains. TDS is a good indicator of the volume of chemical contaminants in a waterbody (EPA 2012).
Water Harness (ppm CaCO3/l)	Water hardness is the amount of dissolved calcium and magnesium in a waterbody but it is usually measured based on the concentration of calcium carbonate (CaCO3). Water hardness is dependent on the geology and bed floor of the waterbody as weathered rocks and soil contributes to the concentration of these solids. If the concentrations of calcium carbonate and magnesium are altered it could be related to an alternation in the surrounding environment of the catchment (EPA 2012).
Alkalinity (mg CaCO3/l)	Alkalinity is a measure of the total amount of base present in the water and therefor the waters ability to naturalize fluctuations of pH. Most alkalinity in waters comes from calcium carbonate leached from soils and rock and similar to water hardness could be related to alternations in land use if levels are altered (EPA 2012).
Chlorphyll-a (µg/l)	Chlorphyll-a is often selected as an indicator of water quality as it is an indicator of phytoplankton abundance and biomass in waters. Factors that can increase as fertilizers or other waste enter the waters. High levels of chlorophyll-a often indicate poor water quality whereas low concentrations indicate good water quality. However, elevated concentrations need to be detected over a longer time period to be able to tell anything about the water quality. The concentration on chlorophyll-a is often higher after rainfall and in the summer months when temperature and light levels are elevated (Bowen *et al*. 2011)

Coliforms bacteria (CFU/100 ml)	Different types of coliforms bacteria are good to test in waters when assessing the water quality, especially the fecal coliforms. Fecal coliforms may expose a danger for human contact if the levels are high and indicates that waters has been contaminated by fecal material from either humans or animals (EPA 2012).

1.2. Water resources and urbanization in Brazil

Today more than 50 % of the world's population lives in urban areas (Castelo *et al*. 2007). This number is around 70 % in Brazil (IBGE 2008). As these rapid changes in population mass and life style occurs in relatively new developed areas of the world there are often less measures taken to prevent and assess the environmental issues that often fallows (BBC 2014). Nearly twelve percent of the world's freshwater supply can be found in Brazil (BBC 2014). Despite this the country is suffering from water scarcity in more and more areas at the same time as an increased number of weather disasters such as flooding and drought are more frequent.

Sewage and other human waste are a growing problem in Brazil, especially in the South and Southeast regions. Here, only 30-35 % of sewage was treated in 2012 (PR Newswire 2014). Rivers have gone from being clear, recreational and full of life to clogged, dirty and far from suitable for human contact and this just in the latest decades. There have also been problems with water scarcity for over a decade, mostly due to heavy exploitation and misuse of surface water resources. Brazil biggest city, São Paulo is recently reported being on the verge of a water crisis where the extensive request for clean water is making the cities taps run dry (New York Times 2015). The biggest reason for this rising acute problem lays in the pollution of rivers, deforestation and population growth as the largest reservoir system serving São Paulo and surroundings is near depletion.

Many of Brazil's biggest cities are experiencing an uncontrolled development and expansion that is leading to an increased occupation of river margins and their floodplains (Pompeu *et al*. 2005). Many of these cities are using river canalization to try to solve these problems such as waste disposal and flooding. But a sharp, hard and often manmade canalized water-channel, instead of a natural one, increases not only water velocity but also pollutant export as the natural uptake and infiltration from surrounding soils are decreased (Turner *et al*. 1991). Such manmade changes in natural river systems are also proven to lower biodiversity (Pompeu *et al*. 2005).

Despite many negative trends and difficulties in Brazilian water management, there have been an increasing awareness and interest in Brazil the last couple of years for the importance of urban watercourses and their beneficial effects on wellbeing and health (IBGE 2014). Rising environmental regulations towards improved sanitation and treated wastewater are today being implemented at many sites in Brazil. The sanitation has improved from 68 % to 79 % between 1990 and 2010 (WHO/UNICEF 2008). Compared with other developing countries, Brazil is starting to turn the negative trend of water misuse around with a higher level of cost recovery and a notable number of technical and financial innovations such as condominium ”housing-block” sewerage as well as an output-based subsidy for treated wastewater called PRODES[3] which is a program created by Brazil's national water agency (ANA).

1.3. Actions in Brazil

Brazil's environmental protection and sustainability legislation is in general advanced and well-planned where laws regarding water and biodiversity have been integrated with the country's politics for almost a century (Hudson *et al*. 1997). Brazil's National Water Agency, ANA, was introduced in the mid 1990's and became a milestone for the Brazilian politics in integrating water based issues between and within different governmental constitutions and power-holders. ANA's most significant role today is to coordinate and implement the National Water Resources Management System (SINGREH), created to ensure sustainability and well-being for Brazilian rivers and lakes. The agency has of today, brought about a general improvement of water resources management and integration between authorizations. ANA have many international partnerships, one of them being the World Bank which in 2011 gave the agency a US $107.4 million loan. This partnership goes back to 1972 and is set to help Brazil to work towards an equitable, reliable and sustainable access in water supply and sanitation services by creating an integrated water sector across the whole of Brazil. In return this is expected to maximize economic and social returns and at the same time ensure environmental and social sustainability.

Another project that the World Bank is sponsoring concerning the water quality and management in Brazil is the Interaguas project. A project formed by the Federal Integrated Water Sector which supports the Government of Brazil in strengthening and improving the integration and capacity among key federal institutions in the water sector. There are five components to the project including water resources management, irrigation and disaster risk, water supply and sanitation, integrated planning for water issues and project management, monitoring and evaluation.

However, in Brazil there are strong conflict between economic growth and environmental sustainability which hardens the environmental goals to be reached and creates tension between national power-holders (BBC 2014). The agriculture boom, strong population increase and urbanization also contribute to further of the country's water issues. Still there are many positive views on Brazil's water management future. There are wide opportunities for national and world spread companies and entrepreneurs to find business ground in Latin America's largest economy (ANA 2013). However, world leaders are urging Brazil to start to deal with issues concerning water and environment in more effective ways as the rising climate change

[3] PRODES is an innovative program by the Brazilian federal government to finance waste water treatment.

by high chance will add to the hardship of the country's already growing water scarcity and pollution problems (ANA 2013). The issue of waste contamination of river systems will with a high probability increase do to climate change and water management will then become harder.

Despite many positive initiative and projects there is still more to be done on the subject of sustainability of rivers in Brazil. Many places around Brazil lack access to piped water and good sanitation (BBC 2014). This along with long-standings tension between the federal, state and municipal governments about their respective responsibilities and roles on the issue are making progress hard (IBGE 2011). Brazil holds the leading position in Latin America when it comes to environmental issues, however, political action are still to scarce for the scale of the work and changes that need to take place in water management in Brazil. Farmers need implemented help to be enabled to manage agriculture and fertilizer usage more efficiently. Monitor and gathering of samples and performing data-analysis are very important for future decision making. More studies like this one need to be carried out and addressed.

Comparing the situation in Frutal however, with other areas of Brazil, it is many aspects that appears better. Slums and poverty are not as great of an issue here as for many close surrounding cities. The municipality has increased a considerable amount in population within the last decades but this increase has been relatively well managed by the ministry and political power-holders within the area. Despite the relatively high standards in water quality that the municipality has been claimed there are still obvious issues to deal with.

1.4. The situation in and around the city of Frutal

Frutal is situated within the state of Minas Gerais which has increased a considerable amount in population over the last decade, and is today the second most populated state in Brazil (IBGE 2014). Suburban development as well as an increased urbanized expansion is taking place in and around the state of Minas Gerais (Ferreira Filho *et al*. 2014). Here, the population size has increased with almost 30 % in around 10 years (Instituto Brasileiro de Geografia e Estatistica 2014).

Minas Gerais is one of Brazil's wealthiest states but also one of the most environmentally damaged from high percentage of sewage and human waste (IBGE 2011). The Frutal municipality is however, one of the most efficient areas in monitoring and waste controlling their water basins (Prefeitura de Frutal 2012). In the years of 2011 and 2012 the city was awarded for its high standards of water quality compared to 28 other municipalities in the southeast parts of Brazil (Prefeitura de Frutal 2012). Political action is growing stronger in the discipline of water monitoring and assessment but even though the municipality of Frutal has made many enhancements in its water managing approach, there are still actions to be taken and improvements to be made.

In Frutal the most important economic activities lays within the agriculture industry including cattle raising and food production. The area around Frutal is an important agriculture producer with a large yearly production of meat and dairy products. There were around 240.000 heads of cattle in 2010 (Prefeitura de Frutal 2012), of which 70.000 were dairy cows. Crop growing, however, is the most common farming activity just outside Frutal city, which occupies more than 150 hectares and include: sugarcane, rubber, oranges, pineapples, soy beans and corn. As well as an increase in the agriculture sector, the latest decade has introduced different industries within the area and these have grown larger as well, including light industry and commerce. Minas Gerais is furthermore, the largest mining state in Brazil. In the Frutal area the diamond mining business has been running for almost 50 years and is a large asset for the whole of the state (Belo Sun Mining 2008). The municipality of Frutal is today one of Minas Gerais fastest economic and social developing areas (Prefeitura de Frutal 2012).

2 Aim

The aim of this study is to examine if two rivers, one urban and one rural, differs in water quality as an effect of the latest decades urbanization that has taken place in and around the city of Frutal in Minas Gerais, Brazil.

2.1 Objectives

The main objectives with this study were to examine if:

There was a difference in water quality between the urban and the rural river within each of the three test seasons of March, July and September, and;

If there was a variation in the rivers water quality between these three seasons, and lastly;

If there is a difference in water quality between the upstream section of Frutal River compared with its downstream section.

The reason for testing the water quality in both rivers in three different seasons was to: firstly, collect more data from each of the measuring points and secondly, to minimize external factors i.e. weather or perhaps other uncounted for conditions affecting the rivers. The main reason however, was to detect significant differences ($P<0.05$) in water quality between the two rivers.

The reason for comparing the three test seasons with one another was to see if there was a significant ($P<0.05$) difference in the tested variables among them and in that case when the largest difference in variables could be detected. Independent variables such as temperature and precipitation will affect the tested variables and to detect when the tested variables were at their highest and lowest levels during the test year, might help in understanding the behavior of the rivers.

Lastly, the objective to compare differences in water quality for different sections of Frutal River was to further point towards the hypothesis of this study, saying that the urban influenced parts of the river has been effected by the urbanization which has lowered the water quality here. Therefor the upstream section of Frutal River, which assumable is in a more natural state, was compared with its downstream sections in relation to Frutal city to see if a difference in water quality could be found.

2.2 Hypothesis

The hypothesis of this study was that the tested variables in the urban, Frutal River, would be of a lower water quality and standard than that of the rural, Bebedouro River due to the urbanization within the urban area of Frutal city. The most effected river stretch would be the downstream section of Frutal River as it is the closest and assumable the most effected by the urbanization in Frutal city.

Furthermore, the difference in water quality between the rivers would be most apparent when the water- volume and flow are the greatest. This assumption was made due to the fact that diffuse waste sources i.e. waste runoff from land more easily can enter the waters in the rivers when these weather conditions are more apparent, creating a larger overland flow and surface runoff. An increased overland flow can cause diffuse sources of waste to enter rivers this is why diffuse sources of waste are expected to have a greater effect within these river systems then any eventual point-source has, when a high flow instead can work as a dilution source. Out of the three tested seasons the month of March is the tested month with the greatest precipitation rate and air temperature. The month of March is therefore expected to have the largest visible and significant differences in the tested variables.

3 Study Area

Field work was undertaken in and around the city of Frutal (20°01' 32.17”S 48°56' 09.62” W) in south-east Brazil approximately 520 meters above sea level. The extent of the study area measured 1431.8 km² in total, covering both rivers and almost a third of Frutal municipality. The Frutal River stretches for 18 kilometers north to south whereas the Bebedouro River stretches for 12.5 kilometers from north to south. Both rivers have smaller side stretches that also have measurement points along them. The distance between the rivers is approximately 2.5 kilometers from the main river channels (Geography department, Universidade Federal de Minas Gerais 2013).

The maximum width for Frutal River is almost 12 meters whereas the Bebedouro River has a maximum width of 8 meters. However, for most locations on both rivers the width is around 4-5 meters. The depth of Frutal River is ranging from 0.4 to 1.9 meters along the whole river stretch whereas Bebedouro River is ranging from 0.2 to 1.2 meters along the whole river stretch (Geography department, Universidade Federal de Minas Gerais 2013).

As mentioned the city of Frutal is located at around 520 meters above sea level, whereas Frutal River, which is located just west of the city, is just below an elevation of 500 meters above sea level for most of the river stretch. The Bebedouro River, approximately 3 kilometers west from the city of Frutal, has an altitude of around 480 meters above sea level for most parts of the river stretch.

The municipality of Frutal had a population of 53.468 inhabitants in 2010 (IBGE 2011) and the expected population size was 57.269 inhabitants for 2014 (citypopulation.de 2014). In the year of 2000 the population size for the municipality was 46.566 inhabitants which is an increase of 23 % over the last 14 years. The municipality of Frutal is located in the south-west parts of Minas Gerais, on the border to the state of São Paulo (Fig. 1).

Figure 1. *Location of Minas gerais within Brazil and the location of Frutal municipality within the state of Minas Gerais. Source: Raphael Lorenzeto 2006.*

The climate in Frutal is classed as tropical, Aw, according to the Köppen-Geiger climate classification. Graphs over the average temperature and precipitation over the period of 2001-2012 for Frutal are presented in Figure 2 and 3. The warmest period over the year is around February and March where temperature reaches a mean of 27 °C and a low mean of 18 °C. For winter and the coldest period that represents July, the mean temperature is around 23 °C and the low mean is around 12 °C. The highest average rain fall for Frutal is usually around summertime in January with almost 300 mm of rain falling for around 20 days/month (Fig. 3). The driest period is around wintertime and July when less than 20 mm rain and 3 wet days is the normal average.

As can be seen in the Figure 2 and 3, the tested season with the highest precipitation rate and temperature is March. In this month there is on an average 190 mm of rain per month whereas for the other tested month the rainfall is 20 mm/month for July and 50 mm/month for September. As mentioned earlier the relatively larger rainfall within the tested days of March is expected to contribute to more diffuse runoff from the lands surrounding the rivers and differences in the rivers could because of this become larger.

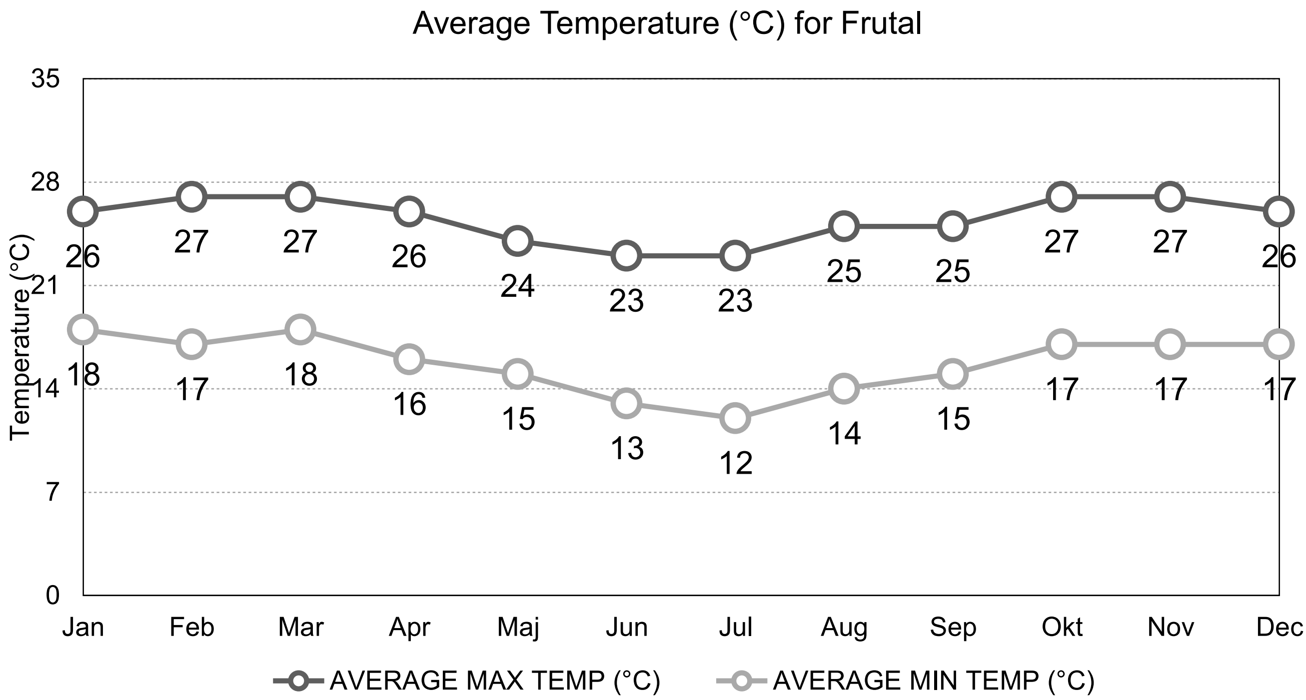

Figure 2. *Average temperature for Frutal, 2001-2012 (Worldweatheronline.com 2015).*

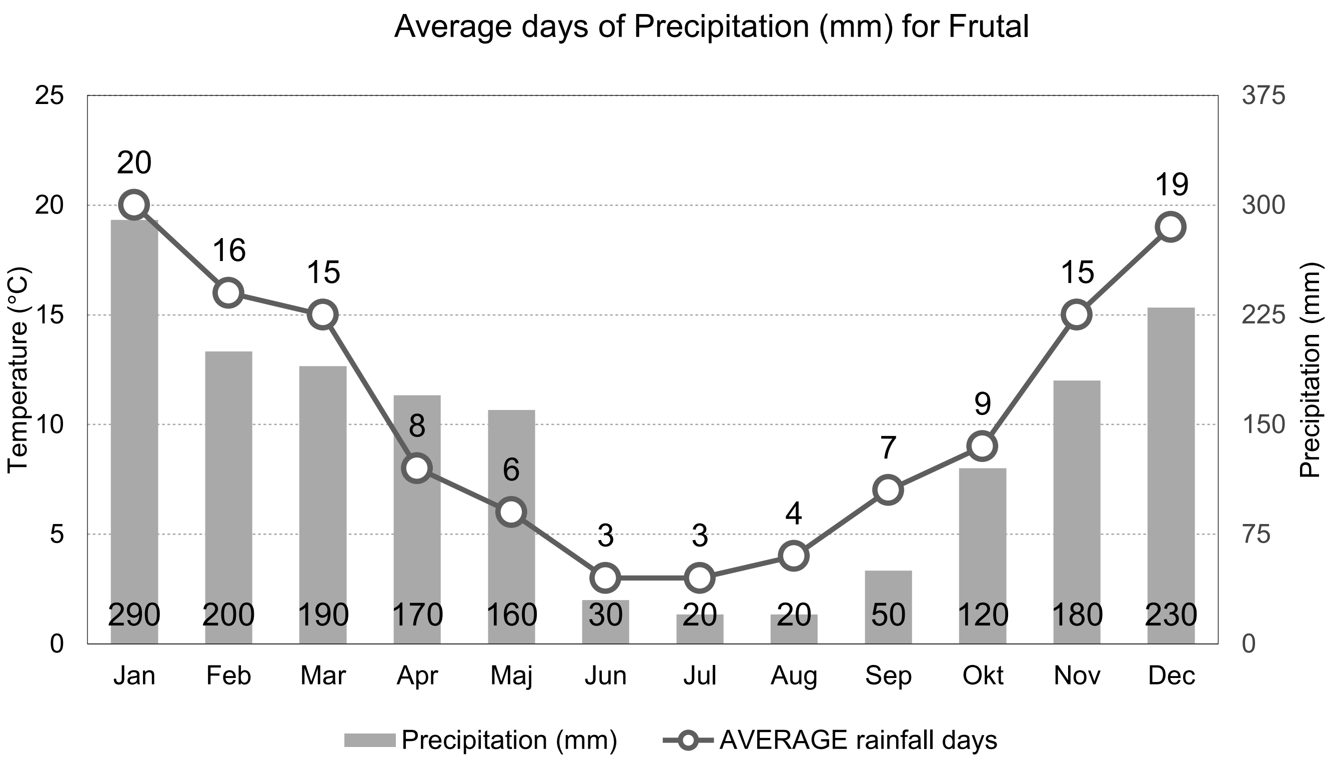

Figure 3. *The average precipitation levels for Frutal, 2001-2012 (Worldweatheronline.com 2015).*

3.1 The choice of rivers and study area

All river systems have different chemical compounds and water properties naturally. To exclude that the Bebedouro and Frutal River are not just different by nature in the tested variables, there need to be theoretically support and historical measurement to decrease this risk. Unfortunately, there does not seem to exist any previous data from the two rivers concerning their water quality. The optimal support for this study and its hypothesis would have been information about the two rivers prior water quality, before the area of Frutal was urbanized at such extent.

However, there are indirect ways to obtain support for conclusions regarding the effect of human activity and the urbanization on the rivers. One way is to compare the two rivers characteristics in regard to physical, geographical and geological features. These characteristic are all very similar for both rivers respectively. The size of the watersheds and the depth including river floor and other properties are strongly comparable between the rivers. Moreover, the nature is similar with a great percentage of farmlands surrounding both rivers as well as agriculture activities. Different types of crop farming are the most common farming activities around both rivers. No major visible or detected differences are to be mentioned between the rivers besides the fact that the rivers are situated with approximately three kilometers difference to the city of Frutal.

Finally, the rurally located measurement points on Frutal River which are situated upstream from the urbanized area of Frutal city are of great interest when determining if and how much Frutal River has been altered by human and urban expansion. The water upstream from the town center is naturally going to be less influenced by the change in land use and other alternations that has occurred in the more urban area of Frutal.

4 Methodology

The measured water quality variables in this study were compared to the standards for aquatic life, recreation and health. The variables that have been selected to reflect the water quality in the two river systems are therefore recommended variables for these types of water quality assessments and the comparable standards are found in the Brazilian Environmental National Council's resolution: CONAMA 357/005 for fresh-, salt and brackish water (Table 2). Different countries often have different standards for acceptable levels looking at these variables and Brazil have a slightly higher acceptable limit for most variables than many other further developed countries.

Table 2. *Maximum values for water quality variables established by the resolution of CONAMA 357/2005 – Water quality standards for fresh- salt and brackish water*.

Variables	Class 1	Class 2	Class 3	Class 4
DO (mg/l)	6	5	4	2
pH	6 to 9	6 to 9	6 to 9	6 to 9
Clorophyll-a (µg/l)	10	30	60	-
Tot. Dissolved solids (ppm)	500	500	500	-
Fecal coliforms (CFU/100 ml)	200	1000	2500	-

Geography students from the Universidade Federal de Minas Gerais gathered the variables for both rivers and each test site. All variables were tested in situ except for the chlorophyll-a and the coliforms that were analyzed in a standard official lab at the University. The variables were collected as part of a bigger project concerning water quality and assessment of river basins in the south parts of Minas Gerais. Important to acknowledge is that all the data has been shared upon agreement.

Three different seasons - September 2012, March 2013 and July 2013 - were selected to perform a water quality assessment on the surface water on each of the two river systems over the different seasons of this year. This was done to see how much the different seasons and weather situations affected the different variables in the rivers. Independent factors such as temperature and precipitation are affecting water systems in their chemical contents, behavior and composition which are why the months furthest apart in the year were selected to detect expected differences. March and July represent summer and winter respectively, and therefore the furthest apart possible weather differences. For the climate type of Aw i.e. tropical, summer is the month when the temperature and precipitation are the highest whereas during winter it is the opposite. The choice of September was more random, it is where the study started and the first collection of the variables where arranged. September is early/mid spring and temperature can vary a lot.

4.1 Sampling design

Water quality sampling sites along Bebedouro River and Frutal River are divided into B, F and R points. The B-points are located along the Bebedouro River and the F-points are situated along the Frutal River with R-points located rurally upstream the Frutal River. The F2 and F3 are also counted as rural points as they are situated upstream on Frutal River and Frutal city. As mentioned these points are together with the R1 and R2 points, of a particular interest when determining if and how much Frutal River has been altered by human and urban expansion.

The distance between the two rivers is approximately 2.5 kilometer where Frutal city is situated where measurement points F14-F17 are located (Fig. 4).

The tested water quality variables including pH, dissolved oxygen, temperature, flow rate, hardness, electric conductivity, total dissolved solids, alkalinity, chlorophyll-a, fecal and total coliforms where collected on all measurement points along both rivers. The pH was measured using a pH meter from Hanna Instruments - Model 98129 and the dissolved oxygen was measured with an oxygen sensor from SGM Lab Solution (Geography department, Universidade Federal de Minas Gerais 2013). The flow rate of both rivers was measured with the float method, a method that by multiplying a cross area of the river/stream by the velocity of the water one can calculate the flow rate. To calculate the water hardness (ppm $CaCO_3$), water samples was taken at every site, seeing how much Ca2+ and Mg2+ each sample contained.

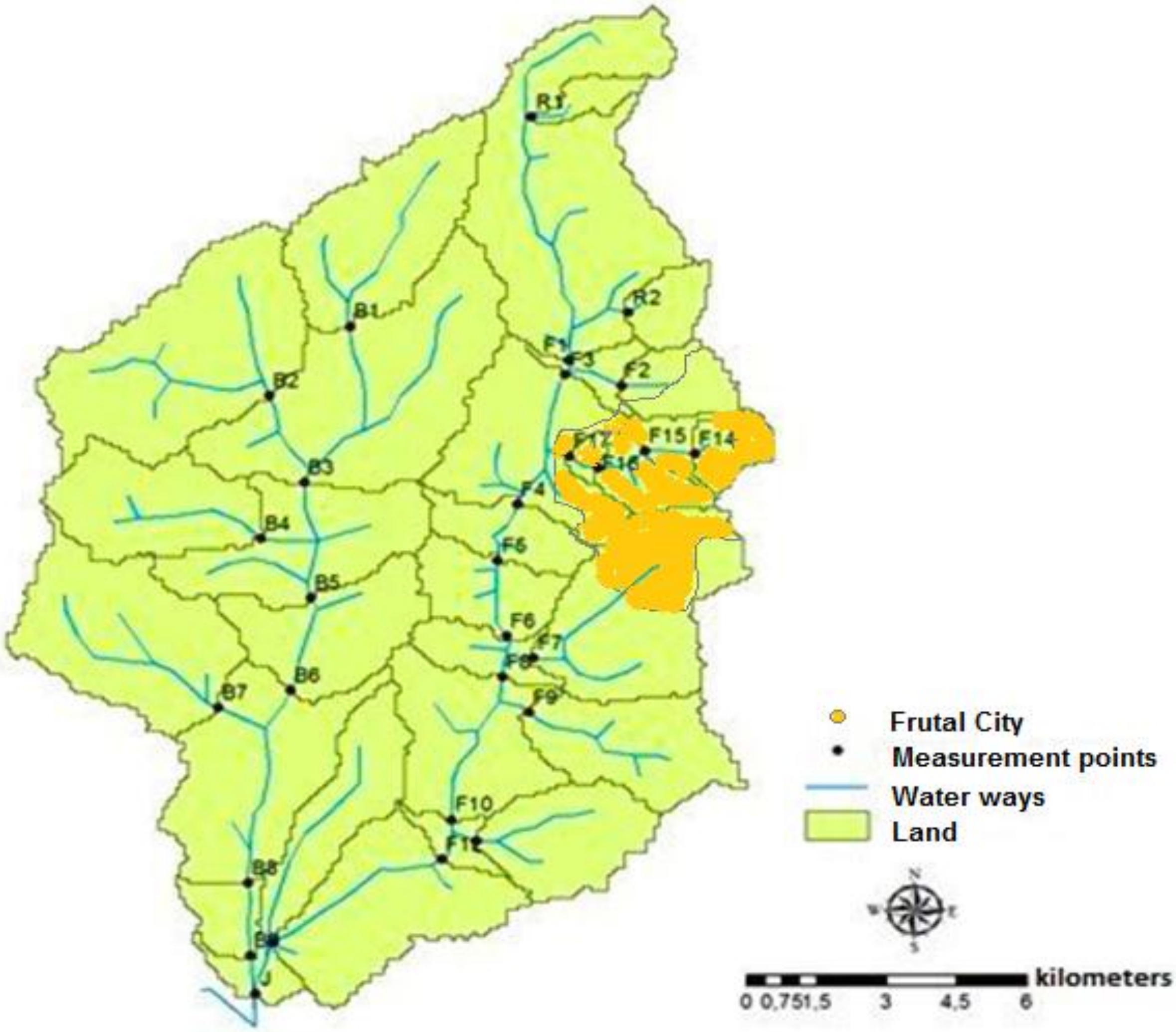

Figure 4. *Map of Frutal and surroundings with measurement points. The points B1-B7, B9, R1, R2, F2 and F3 are rural points with little settlement around whereas the points F4-F10, F12 and F14-F17 are all located on the Frutal River either downstream or in close proximity to the city.*

4.2 Data analysis

Mean values for all the seasons measurements for both Bebedouro River and Frutal River were put together in tables (Table 3-5). To test the third objective in this study i.e. if the up-stream section of Frutal River is cleaner than the downstream section, the mean for the up-stream measurement points (R1, R2, F2 and F3) was calculated. This was to compare these means with the means for the whole of Frutal River to see if there was a visual difference be-tween the tested variables in water quality.

One-way ANOVA was conducted to test the second objective in this study i.e. if the three test seasons had a significantly difference in tested variables (Table 6). One-way ANOVA compared the means of dependent variables between the two rivers over all the tested seasons. This was conducted to find out whether there was a significant difference between these two rivers over time i.e. for different seasons over the year. Independent environmental variables were also tested for differences potentially explaining differences in dependent variables. Tukey's post-hoc test were calculated to show if and which season that was significantly different.

To test the first objective in this study i.e. if the two tested rivers had a significant difference in water quality, an Independent t-test was conducted to look for significant variations between the two rivers for all the dependent and independent variables and this for all the measurement sites (Fig. 4) along both rivers (Table 7-9).

5 Results

A comparison between the eleven tested variables for the rural, Bebedouro River and the urban Frutal River over the three different seasons reveals significant differences in a majority of the water quality variables (Table 7-9). The only variables that did not show any significant differences between the rivers in any of the test months were chlorophyll-a and flow. The rest of the tested variables had a significant ($P<0.05$) difference when statistically comparing the test rivers.

Furthermore, the rural, Bebedouro River was within the limits for class 1, which is the highest class with cleanest water, for almost all of the comparable variables according to Brazil's National Environmental Council and the paragraph of CONAMA 357/2005. Whereas the downstream section of the urban Frutal River, is a class 3, a lower ranked water quality, for DO, chlorophyll-a and total coliforms according to CONAMA 357/2005 (Table 2).

5.1 The mean values for the rural - Bebedouro River and the urban – Frutal River and each of the water quality variables for each of the seasons.

The mean values for both rivers in each of the test months have been plotted in tables to get an overview of the tested variables and their differences in levels between the rivers. The Frutal River showed a higher mean in all of the measured variables except for total hardness and dissolved oxygen. Besides the means from the tested variables from Frutal- and Bebedouro River, the means from the upstream located points on Frutal River has been plotted.

Table 3. *Mean values for the tested variables for* ***11-19th September 2012.***

Mean for measured parameters - September 2012

	Dissolved Oxygen (mg/l)	Tot. Dissolved solids (ppm)	Temperature (°C)	Flow (m³/s)	pH	Tot. Alkalinity (mg CaCO3/l)	Tot. Hardness (ppm CaCO3/l)	Electric conductivity (µS/cm)	Chlorophyll-a (µg/l)	Fecal coliforms (CFU/100 ml)	Tot. coliforms (CFU/ 100 ml)
Urban mean	4.6	83.7	26.4	.6	7.2	59.2	51.2	158.9	15.5	3145.4	37058.3
Rural mean	6.3	22.6	26.2	.4	7.0	35.3	24.4	45.8	1.01	2932.3	3559.9
Urban mean - *Upstream	6.1	25.3	25.4	.4	7.0	41.9	-	51.6	2.0	311	998.2

**Points R1, R2, F2 and F3 on Frutal River, located upstream from the urban area of Frutal. (n = 24)*

Table 4. *Mean values for the tested variables for **4-8th March 2013**.*

Mean for measured parameters - March 2013

	Dissolved Oxygen (mg/l)	Tot. Dissolved solids (ppm)	Temperature (°C)	Flow (m^3/s)		Tot. Alkalinity (mg CaCO3/l)	Tot. Hardness (ppm CaCO3/l)	Electric conductivity (µS/cm)	Chlorophyll-a (µg/l)	Fecal coliforms (CFU/100 ml)	Tot. coliforms (CFU/ 100 ml)
Urban mean	4.3	73.7	26.5	1.4	7.0	27.1	36.7	113.6	10.6	30953.6	71210.9
Rural mean	5.7	42.5	26.4	1.2	6.8	17.5	44.0	65.6	2.7	2932.5	32745.8
Urban mean - *Upstream	5.5	47.8	25.1	.2	6.6	84.8	37.0	73.3	5.7	975.0	17217.6

**Points R1, R2, F2 and F3 on Frutal River, located upstream from the urban area of Frutal. (n = 24)*

Table 5. *Mean values for the tested variables for **17-19th July 2013**.*

Mean for measured parameters - July 2013

	Dissolved Oxygen (mg/l)	Tot. Dissolved solids (ppm)	Temperature (°C)	Flow (m^3/s)	pH	Tot. Alkalinity (mg CaCO3/l)	Tot. Hardness (ppm CaCO3/l)	Electric conductivity (µS/cm)	Chlorophyll-a (µg/l)	Fecal coliforms (CFU/100 ml)	Tot. coliforms (CFU/ 100 ml)
Urban mean	3.4	7.2	21.2	1.9	7.2	79.7	48.0	105.8	50.6	18103.3	43448.3
Rural mean	5.4	7.2	19.5	1.9	7.2	24.7	64.5	58.4	5.1	490.9	7218.3
Urban-ban-mean - *Upstream	4.7	37.5	20.0	0.6	7.3	21.4	48.1	74.3	1.3	465	11485

**Points R1, R2, F2 and F3 on Frutal River, located upstream from the urban area of Frutal. (n = 24)*

5.2 Seasonal comparison of the rivers with One-way ANOVA

Comparing the different variables over the different seasons was executed to detect seasonal behavior of the rivers. Using One-way ANOVA revealed that more than half of the tested variables varied significantly between the seasons of year 2012-13. Dissolved oxygen varied significantly between September and July, being considerable larger in September (Table 6). Temperature, which expected, had a high significantly difference between the seasons and the same was true for the flow in the rivers, but for the flow only September and July differed significantly, July being considerable higher in flow speed than September (Table 6).

Factors as pH, total alkalinity and total hardness all had a significant variation between the seasons (Table 6). However, only pH was the variable being significantly different over all seasons whereas total alkalinity was only considerable higher in September compared to March and total hardness was only considerable higher in July compared with September. Total coliforms where significantly different between September and March, March being considerable higher in numbers than September. All the other variables did not have a significantly difference between each other (Table 6).

Table 6. *One-way **ANOVA** showing significant differences in water quality over the test seasons (September, March and July 2012-2013).*

Variable	df.	F	Tukey’s post-hoc
Dissolved Oxygen (DO)	2/69	2.924^{ns}	September>July*
Total dissolved solids (TDS)	2/69	0.645^{ns}	Not significant
Temperature	2/69	92.895***	September>July***and March>July***
Flow	2/69	8.620***	September<July***
pH	2/69	13.832***	September>March***
Total alkalinity	2/69	5.917**	September>March**
Total hardness	2/69	5.159**	September<July**
Electric conductivity (EC)	2/69	0.277^{ns}	Not significant
Chlorophyll-a	2/69	0.787^{ns}	Not significant
Fecal coliforms	2/69	2.083^{ns}	Not significant
Total coliforms	2/69	4.119*	September<March*

*p=<0.05, **p<0.01, ***p<0.001, ^{ns}p=>0.05 (n=24)

5.3 Comparison of the rivers within each month using Independent t-test

Using an Independent t-test revealed that DO varied significantly between both rivers in each of the tested seasons (Table 7-9). TDS varied significantly between the rivers within March and July but not within September (Table 8 and 9). Temperature varied significantly between the two rivers only within July (Table 9). The pH varied significantly between the rivers only within March (Table 8). Total alkalinity varied significantly between the two rivers in September and March but not in July (Table 7 and 8). The hardness of the rivers varied significantly only in September (Table 7). The EC in the two rivers varied significantly within March and July but not September (Table 8 and 9). For the variables of flow and chlorophyll-a there were no significantly variation within any of the months. However, all the months showed significantly variation in total coliforms within each month whereas it was only March that had a slight significant variation between the two rivers in fecal coliforms this year (Table 8).

Table 7-9. Independent **t-test** showing significant differences in water quality between the Bebedouro and Frutal River, 2012-13, for each of the test months of September, March and July.

Table 7. *The differences in water quality between the urban and rural river in September:*

Variable	df.	t	Sig. (2-tailed)
Dissolved Oxygen (DO)	22	-2.997	0.007 urban<rural**
Total dissolved solids (TDS)	11.358	1.863	0.088
Temperature	19.685	0.301	0.767
Flow	22	1.308	0.204
pH	22	1.567	0.131
Total alkalinity	22	2.114	0.046 urban>rural*
Total hardness	14.774	3.842	0.002 urban>rural**
Electric conductivity (EC)	11.465	1.916	0.081
Chlorophyll-a	11.013	1.397	0.190
Fecal coliforms	22	0.066	0.948
Total coliforms	11.638	2.685	0.020 urban>rural*

*p=<0.05, **p<0.01, ***p<0.001, ^{ns}p=>0.05 (n=24)

Table 8. *The differences in water quality between the urban and rural river in March:*

Variable	df.	t	Sig. (2 tailed)
Dissolved Oxygen (DO)	22	-2.997	0.007 urban<rural**
Total dissolved solids (TDS)	18.107	2.916	0.009 urban>rural**
Temperature	22	0.075	0.941
Flow	21	0.717	0.481
pH	22	2.718	0.013 urban>rural*
Total alkalinity	22	2.372	0.027 urban>rural*
Total hardness	22	-1.294	0.209
Electric conductivity (EC)	17.986	2.920	0.009 urban>rural**
Chlorophyll-a	13.642	1.702	0.111
Fecal coliforms	11.433	2.219	0.048 urban>rural*
Total coliforms	22	2.184	0.040 urban>rural*

*p=<0.05, **p<0.01, ***p<0.001, ^{ns}p=>0.05 (n=24)

Table 9. *The differences in water quality between the urban and rural river in July:*

Variable	df.	t	Sig. (2-tailed)
Dissolved Oxygen (DO)	22	-4.320	0.000 urban<rural***
Total dissolved solids (TDS)	22	3.307	0.003 urban>rural**
Temperature	22	2.772	0.011 urban>rural*
Flow	21	0.019	0.985
pH	22	-1.145	0.264
Total alkalinity	2.063	2.081	0.169
Total hardness	8	-1.519	0.167

Electric conductivity (EC)	22	3.336	0.003	urban>rural**
Chlorophyll-a	2.005	0.920	0.454	
Fecal coliforms	11.0022	1.837	0.093	
Total coliforms	11.320	2.706	0.020	urban>rural*

*p=<0.05, **p<0.01, ***p<0.001, ^{ns}p=>0.05 (n=24)

6 Discussion

In the first part of the discussion a broader perspective of the study and its aim will be discussed including its objectives and hypothesis. After this the differences in water quality will be discussed further. The shown differences in the tested variables between the rivers will be discussed and more so, what affect this comprises. In the section after this, the discussion will be focused on a broader perspective looking at the whole of Brazil and the water quality and management sector. The last part of the discussion focus on the future for the Frutal River and suggestions on what can be done in order to increase the poorer water quality detected in this river.

6.1 The derived results

The acquired results in this study support its hypothesis; there is a difference in water quality between the tested urban- and rural river. This difference is considerable for most tested variables and for some variables there are significantly ($P<0.05$ and $P<0.01$) differences between the rivers when performing statistical tests (Independent t-test and One-way ANOVA) (Table 6-9). This result support the first objective in this study, the Frutal River which is situated closer to the urban area of Frutal city is more effected by the last decades urbanization and its consequences compared to the rural, Bebedouro River.

Looking at the significant ($P<0.05$) differences for the two rivers in each tested season the month with the most variation in the measured variables is March. In this month pH and fecal coliforms are significantly different between the rivers as Frutal River has a significantly larger value in both of these variables. This result is not seen in any of the other two seasons. This further supports the hypothesis and the second objective in this study. The significantly poorer water quality within the month of March is pointing at a larger influence from diffuse sources such as land runoff from the urban areas rather than from point-sources on the river. The increased temperature combined with an increase in precipitation which leads to a higher water flow and volume in the test rivers for this season, increases some of the variables i.e. pH, total alkalinity, EC and fecal coliforms. These variables are not seen to be significantly different in any of the other test seasons.

Comparing the differences in means for the variables over the rivers shows a difference as well. The Frutal River has a poorer water quality for all the tested variables and looking at the means for the upstream measurement points for Frutal River and comparing them with the total means for the Frutal River, there is also a visible difference in water quality (Table 2-4). The measured points upstream from the urban area of Frutal have a better water quality than the average of the tested variables for the whole of Frutal River.

Worth pointing out is that the only measured variables that always stays significantly different ($P<0.01$) between the two rivers is dissolved oxygen. There is less DO in Frutal River which both points at a higher mean temperature in this river but also the probability that more waste water from sewage, from both diffuse sources, point-sources and plants, containing organic material is present in this river. The organic matter in the waste is being decomposed by microorganisms that use the rivers oxygen in the process which then decreases (EPA 1992). The low concentrates of DO in Frutal River may lead to a decrease in biodiversity (Interlandi *et al*. 2003).

6.2 Differences in water quality between the rivers

Temperature and flow rate

Temperature will affect other variables tested in this study and therefore it is of interest to look at the results derived from the independent t-test, to see if there was a significantly difference in temperature between the rivers for each month. The only month that had a significant difference ($P<0.05$) in temperature between the rivers was July. However, the result shows that Frutal River had a higher temperature in all of the months. This supports LeBlanc *et al*. (1997) study, showing that an intensified land usage affects the surrounding water shed and increases its temperature.

There was a large significant difference between September and July in flow rate whereas within each month there were no detected significant differences between the two rivers in this variable. Between the seasons, July had a significant larger flow rate than September had (Table 6). Between the rivers, Frutal River always had the highest flow rate. As Interlandi *et al*. (2003) paper presented, the flow is a large determining factor for the water quality in a river. The results in this study points at a disturbing high flow in the Frutal River, that might not only be a result of natural causes but perhaps also from other factors, relating to urbanization. Urban areas often have a larger over land flow than more natural land, as concrete and cement often stops water from penetrating down into the ground. A larger overland flow leads to a faster peak flow which often as well carries pollution easier into the rivers. A water body that has had its flow rate unbalanced is demonstrated to cause other factors such as bacteria, chlorophyll-a, turbidity to a possible increase, a consequence that may be seen in this study.

pH, total alkalinity and hardness

The pH was significantly different between the two rivers in March, where the Frutal River had a significantly higher pH than Bebedouro River (Table 8). March has the highest air temperature out of the tested seasons and pH is prone to sink when temperature increases as a result of dissociation. Looking at Table 3-5 with mean values for the tested variables over all the seasons, it is a clear decrease in pH in March compared to the other months. However, looking at all the months mean values for pH it is not always a lower pH in the Bebedouro River compared to Frutal River. For July the Bebedouro River has a slightly higher pH than Frutal River has. This could be the effect of temperature being significantly lower in Bebedouro River. pH was over all higher in the urban Frutal River compared to the rural Bebedouro River. This suggest with agreement from Fisher *et al*. (2000) that an increased land use correlates positively with an increased over all pH. This can be a consequence, of as earlier mentioned, pollution from point sources or NPS, entering the river.

Total alkalinity was higher in value for the Frutal River within all the tested seasons with a significant difference (P<0.05) between September and March. However, The Bebedouro River had more stable levels of total alkalinity and this could very well indicate that the river is less affected by urbanization and alternations in land cover compared to the Frutal River. More unstable variables in Frutal River compared to more stable levels in Bebedouro River can be seen as a sign that something else is affecting the unstable variables in Frutal River, more than natural factors, example a seasonal increase in fertilization and waste from point sources or perhaps sewage leakage (Ferreira da Fonseca *et al*. 2007, Mariely *et al*. 2002). Even though a fairly high concentration of alkalinity is beneficial for rivers, this may indicate that an external source of calcium carbonate, CaCO3, is being leached into the river from rocks and soil. A process that may be enhanced when rocks and soil have been broken up for any reason, for example by mining or urban development. There are mining activities further up in the state of Frutal but it is unclear if this could affect the waters in the tested rivers. However, the urban development might very well contribute with leaching of sediment and rocks entering the rivers.

The mean values for water hardness was larger in Bebedouro River for all seasons expect for the examined days in September (Table 3-5). A higher level of total hardness is expected to be measured in a river less altered in neutrality and for the tested days in September the differences in hardness between the rivers are highly significant (P<0.01) (Table 7). This is suggesting that Bebedouro River is in a more natural state than the Frutal River and this is an indication that Frutal River is affected by the increased urbanization happening around and within the Frutal area.

Electric conductivity

The significant (P<0.01) difference between the rivers for this parameter within March and July, strongly indicates that there might be a direct discharge from a point-source or perhaps other diffuse sources of pollution leaking into the river of Frutal. Moreover, it supports the second objective in this study i.e. that March, the tested month with the highest flow and water volume will have an increase in diffuse sources of pollutants and other variables in the rivers, causing the conductivity to rise and the difference between the test rivers to increase further.

The elevated levels of EC in the urban downstream section of Frutal River are quite expected, as an increased level of EC occurs when a larger fraction of the water originates from ground water flow. The ground water flow or base flow is usually larger downstream of a river and as an effect the concentration of solutes are elevated which leads to an increased EC. However, comparing the levels of EC between the upstream section and the downstream section on Frutal River (Table 3) the increase of EC is relatively large when moving downstream the river. The levels of EC is also considerable larger for all measurement points along Frutal River compared to Bebedouro River which may just indicate that the urban river has a larger ground water flow and another chemical composition than the rural river but it might indicate that the water of Frutal River is slightly polluted and can also show an indicative of salinity problems that also might be observed in eutrophic waters where plant nutrients and fertilizers are in greater abundance (Interlandi *et al*. 2003). The increased precipitation rate for the month of March might also be contributing to a larger surface runoff from the urban area allowing more diffuse pollution sources to be watched into the river, causing the EC to rise.

Coliforms & Chlorophyll-a

Levels of total coliforms were significantly higher in the Frutal River within all the tested seasons. This suggests that the Frutal River is affected by more anthropogenic factors than what the Bebedouro River is as a high level of coliforms often correlates with human activity and sewage leakage. Animal sewage is also likely to be present in the measured concentration of total coliforms considering the agriculture lands up north from the city. However, the cattle industry and farmlands are not that close in proximity to any of the rivers but the ground water and the risk that cattle enter the rivers for water or similar risks cannot be excluded.

March was the tested season when the differences between the rivers for this tested variable was the largest (Table 8). This is possibly an effect of the warmer air- and water temperature in this season which gives an increase in growth to microorganism such as different types of coliforms and different types of chlorophyll. The higher temperature combined with the fact of an increase in precipitation during the month of March may lead to more diffuse sources of waste and pollution entering the watershed of Frutal.

The levels of chlorophyll-a were not significantly different between the rivers or any of the seasons when the rivers water quality were tested. However, the levels were always higher in the Frutal River which most probably is part of a positive increase in other factors such as increase in nitrate, phosphorus and other non-minerals, all very important and common ingredients in fertilizing within the agriculture and farming sector (Chakoumakos *et al*. 1979). These are indicators that the Frutal River is more affected than the Bebedouro River, by the increased land usage taking place in and around the city of Frutal. Furthermore, the slightly higher water temperature is prone to increase the chlorophyll-a concentrations in the urban river as well as nutrients from eventually waste from humans may do.

Other differences

Both rivers and their surroundings lack enough protection from fertilizer, pollutions and other human waste. The result of this study indicates that the Frutal River is more exposed to these hazards than the Bebedouro River is. The differences that have been detected between the rivers are by high probability a consequence of the higher percentage of land use and urban areas around Frutal River compared to Bebedouro River. Moreover, sewage- and leakage problems are suspected to be higher in and around the Frutal River, which also is what the result is indicating, looking at the differences of fecal coliforms and total coliforms between the rivers.

The Frutal River is expected to have a slightly elevated surface runoff compared to the Bebedouro River as the urban area of Frutal with pavement and buildings are hindering the percolation of the water down to the soil to the aquifer. This allows for more anthropogenic contaminants to be dissolved or suspended in runoff which may create water pollution in nearby rivers and water bodies.

Fertilizer content and pollution differences between the rivers is a harder factor to determine and a broader study should of been carried out measuring fertilizer contents such as nitrogen, phosphorus, sulfur and other non-metals in the rivers. However the chlorophyll-a is measured to be approximately 500 percent higher in the Frutal River which indicates that this river contains more fertilizer contents then the rural river.

The Frutal River has, compared to Bebedouro River, a lower water quality according to these results. March was the measured period when the two rivers were the most different in water quality comparing the measurement values. This result was fairly expected for the summer months, when chemical and biological variables within a river system often become more apparent as the temperature rise gives a higher capability for reactions to take place combined with a higher flow as water volume increases due to the increased amount of precipitation. This was also the period when the dissolved oxygen was at its lowest and this too contributes to a more sensitive and lower water quality in Frutal River.

6.3 What can be done?

One proven effective way to lower human waste and sewage in smaller river catchments are by introducing and installing sewage treatment plants. A good example of this, from Mariely *et al*. (2002), showed how the smaller Piracicamirim stream in Piracicaba, north of São Paulo, successfully started to collect 90 percent of the organic load after introducing sewage plants in the Piracicamirim catchment. Prior to installing the sewage plants, the catchment was heavily exposed and polluted by human waste and approximately 150 L s^{-1} was directly dumped into the Piracicamirim stream. The Mariely *et al*. 2002 study's result is of particular interests for the Frutal River. Firstly, because Frutal city itself is very similar to the Piracicaba city in population size, industrial development and climate. Secondly, because Frutal River is about the same size, a smaller catchment, similar to the Piracicamirim stream. As the Piracicamirim stream has many qualities similar to Frutal River and the results from the implemented sewage plants in Piracicaba had such positive outcomes, it is strongly suggests that Frutal River undergoes this regime as well.

Another study from Liu *et al*. (2013), concerning non-point source (NPS) pollution and how to best reduce these, made analysis of several scenarios using SWAT (Soil and Water Assessment Tool). Primary factors to influence NPS pollution in the tested Xiangxi watershed, where studied to be changes in land use, fertilizer management and tillage management. Suggested ways to decrease NPS pollution loads in the Xiangxi watershed included tillage and contour farming which was studied to reduce runoff by 16 percent, total nitrogen by nine percent and total phosphorus by seven percent. This is a promising result for the future of other smaller polluted watersheds, including Frutal River.

Another important and increasingly recognized method to address complex water management challenges in Brazil is Green Infrastructure (GI). The GI method refers to natural and alternative options to conventional “grey” water infrastructure, when providing service for water recourse management (Benedict *et al*. 2006). The main idea with GI is that the environment and different components in it will offer multiple benefits if there in a healthy state, serving both humans and nature over time. This is an increasingly important model to integrate into politics and cities infrastructures to create a well working and lasting eco-life and biodiversity.

For Frutal River to experience these positive changes too, there need to be more and better implemented political action in Brazil and the state of Minas Gerais. Awareness needs to be established for the water quality in rivers and the subject needs to be given a larger role in government on national, state and local level. An identification of the environmental value that water has and implemented schemes on how to hold pollutant and waste levels down need to be addressed and practiced. River pollutant management and water quality monitoring together with a better agriculture management, will help to reduce the environmental hazards that is damaging the water in Frutal River and other urban watersheds.

Compared to other municipalities within the southeast parts of Brazil, the municipality of Frutal has a relatively good water management policy and standards (Prefeitura de Frutal 2012). However, this area has a fairly new infrastructure were there are clear evidence derived from the result of this study pointing towards a lack of protection and management to deal with water quality issues and the problems causing them.

6.4 Thoughts on this study

Furthermore, it would have been interesting to measure other contributing aspects, for example the biodiversity within this area and see if it differs between the two rivers. There is a high possibility that biological spread and species sturdiness differs between the rural Bebedouro River and the urban Frutal River as a high percentage of pollutants as well as a less natural river system leads to biodiversity decay. As Pompeu *et al*. (2005) suggest in their study, this often happens when a river is being urbanized without the right protections and in uncontrolled ways.

Furthermore, other variables such as non-metals for example; nitrogen, sulfur and phosphorus would of been of great use in this study as well. These variables could of added knowledge about the state of both rivers water quality and the grade of pollution from fertilizer usage and also sewage concentrations.

6.5 Sources of error

The data used in this study was collected over a few days in three different months. There are many significant differences ($P<0.05$) discovered between the examined urban and rural river. However to get a more accurate and valid scientific base more studies need to be carried out within this area looking at water quality. A larger amount of measurement points should have been measured as well as more days for each measuring period and this should have been carried out for more years to improve research's statistical robustness.

Furthermore, the fact that there is little or no background data of the water quality for the rivers limit the conclusion about what has caused the rivers to be different in water quality during the tested period of 2012-2013. Also the limited knowledge about the area in more detail is a concern, as the surrounding environment and the activity close to the rivers determine their chemical and physical water properties. Better knowledge about these factors would have helped in the determination of how the rivers water quality is formed. There is also a risk to consider in the sharing of the data from the students that performed the measurements. Unfortunately, there cannot be a way to validate the sampling design and the measures taken from the students in the evaluation and testing of the collected variables. The information about how the variables were collected is a lacking source that could not be retrieved for most variables. The connection to these students for me is also relatively weak as the only mediator has been a friend of mine from Brazil, of who received these measurements from the students herself which she later shared with me.

Moreover, it was hard to find legit data from Brazil's National Environmental Council and the paragraph of CONAMA 357/2005 lack qualitative boundaries for half of the examined variables in this study. All of which makes it difficult to compare the measured variables from the Frutal and Bebedouro River with other water bodies and compare the result with national standards. Besides the lacking standards in the paragraph of CONAMA 357/2005, there was also little or inefficient information about the municipality of Frutal and other useful information such as national standards online, in English. Translating from Portuguese to English creates a risk of a source of error which made the background knowledge about this study area harder to gather. It also made the comparison to other rivers and water quality standards harder.

The question if the detected water quality differences between the rivers can be solely connected to the urbanization or if there even is a connection, remains. It is based on the results from this study and the background information, hard to with infallibly proof point towards the urbanization being the cause of this difference in water quality. However, there seem to be an influence of the urban development taking place within the municipality of Frutal upon the water quality in the Frutal River. This as other external factors influencing both the rural and urban river are very similar. At least all the evaluable external factors that were to be found, that may affect the rivers and their water content, are similar between the rivers.

7 Conclusion

The hypothesis of this study was supported i.e. the past decades urbanization within the municipality of Frutal in Minas Gerais, Brazil, has with fairly high probability lowered the water quality in the urban, Frutal River more than for the rural, Bebedouro River.

The differences in water quality between the tested rivers are significant ($P<0.05$) for 9 out of eleven tested variables; temperature, pH, dissolved oxygen, total hardness, total alkalinity, fecal coliforms, total coliforms and total dissolved solids. The difference in water quality is also apparent between the different test seasons of March, July and September, being poorest in March when the precipitation and water flow is the highest.

This is suggested being the consequence of the urbanization in the municipality of Frutal and the lack of consisting and efficient environmental control.

7.1 Closing remarks

Water quality assessments of rivers are of a rapidly rising interest for nations as well as the whole of human kind. Brazil plays an especially interesting part on the subject of water quality as a large problem within this area has been detected and the sensitivity the country possess, with its unique biota and species. Still too little has been done to change what is fact, rivers are being abused and mistreated to cope with anthropogenic demand without enough thought being given to the consequences it has on the natural environment and ecosystem. Large problems with human waste, sewage and fertilizer leakage from farmland and industry are among the state of Minas Gerais and Brazil's largest challenges to face. In this paper it is clear that, even though the studied rivers are not geographically far apart, their difference in water quality is significant. Most likely the reason for this is the far greater influence from anthropogenic activities affecting the urban Frutal River compared to the more rural Bebedouro River.

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