CONILON Coffee

3rd Edition

Updated and expanded

The Coffea canephora produced in Brazil

Romário Gava Ferrão
Aymbiré Francisco Almeida da Fonseca
Maria Amélia Gava Ferrão
Lúcio Herzog De Muner
TECHNICAL EDITORS

Capixaba Institute for Research, Technical Assistance and Rural Extension
Rua Afonso Sarlo, 160 - Bento Ferreira - CEP: 29052-010 - Vitória-ES - Brasil - Caixa Postal: 391
Telephone: 55 27 3636 9888; 55 27 3636 9846 - coordenacaoeditorial@incaper.es.gov.br | www.incaper.es.gov.br

ISBN: 978-85-89274-32-6
Editor: Incaper
Format: digital/printed
May 2019

GRAPHIC DESIGN, ELECTRONIC EDITING, FINAL ARTWORK AND COVER
Laudeci Maria Maia Bravin

ENGLISH TRANSLATION
Marcelle Gualda Pasolini

CATALOGING
Merielem Frasson da Silva

PHOTO CREDIT
Augusto Barraque, Incaper and authors' collection

EDITORIAL COORDINATION AND PROOFREADING OF STANDARDIZATION
Liliâm Maria Ventorim Ferrão

Incaper - Rui Tendinha Library
International Cataloging Data in Publication (ICP)

C129 Conilon Coffee / technical editors, Romário Gava Ferrão ... [et al.]; english translation Marcelle Gualda Pasolini. - 3 edition updated and expanded. - Vitória, ES : Incaper, 2019.
974p.: il. color.

Translated from: Café Conilon, 2017 - Incaper.
System Required: Adobe Reader
Access mode: https://bibliotecaruitendinha.incaper.es.gov.br/
ISBN: 978-85-89274-32-6

1. Brazil. 2. Espírito Santo (State). 3. Coffee Cultivation. 4. Conilon Coffee I. FERRÃO, Romário Gava (Ed.). II. FONSECA, Aymbiré Francisco Almeida da (Ed.). III. FERRÃO, Maria Amélia Gava (Ed.). IV. DE MUNER, Lúcio Herzog (Ed.). V. Capixaba Institute for Research, Technical Assistance and Rural Extension. VI. Title.

CDD: 633.73

Elaborated by Merielem Frasson da Silva - CRB-6 ES/675

22

Management of Conilon Coffee Wastewater

Sammy Fernandes Soares, Aldemar Polonini Moreli, Sérgio Maurício Lopes Donzeles, Luíz Carlos Prezotti, Juarez Souza e Silva and Edvaldo Fialho dos Reis

1 INTRODUCTION

The processing of the coffee tree fruits, in order to obtain the peeled cherry, involves cleaning operations, which do not consume water, and washing, hulling and mucilage removal, in which the water is used and it is added several residues to it, generating the "coffee wastewater"(CWW).

The cleaning operation is done in the field and in the processing unit and branches and leaves are removed by shaking and sieving. Washing is performed by removing fragments of branches and leaves, the dirt on the fruits and other impurities that come together during the coffee harvesting. The washing also makes the separation of the "coffee bean" from the cherry and green fruits possible, which are taken to the huller, where the cherry fruits are peeled and separated from the green ones. To complete the processing, it is common to remove part of the mucilage that sticks to the peeled cherry coffee.

The impurities removal and the fruits separation in different batches- floating coffee, green and cherry- allows to adequate the drying process in order to reduce the time and cost of this operation and to confer greater market value to the coffee. Because of the prospect of cost reduction and adding value to the product, the number of coffee grower interested in producing the peeled cherry coffee is increasing.

However, this coffee processing consumes loads of water and generates CWW, rich in organic material, with potential to pollute the environment. In order to enjoy the advantages that the production of peeled cherries makes possible, it is fundamental to minimize the water consume and the generation of CWW in its processing and to adapt its use and destination to reduce environmental impacts.

This chapter approaches several aspects related to CWW generation, reuse, disposal and utilization and a synthesis of relevant legislation aiming to subsidize the planning, implementation and operation of wet processing coffee units.

2 LEGISLATION

The licensing process for agricultural activities that make use of water requires as a prerequisite the water allocation document ensuring the right to use water resources, which is also essential to request funding through public and private financial institutions, as well as to obtain quality certification (EUCLYDES, 2007).

Law Nº 9433, of January 8, 1997, established the National Policy on Water Resources, establishing its foundations, objectives, guidelines and instruments. The water allocation is one of the instruments of this policy, which aims to ensure the quantitative and qualitative control of water use and the effective exercise of the rights of access to the water resources. This control aims to avoid conflicts between water resources users in the Brazilian territory (BRASIL, 1997).

The water allocation of bodies of water in the union domain is done by the Agência Nacional de Águas - ANA (National Water Agency) and, in the other bodies of water, by state institutions that are responsible for environmental management. In Espírito Santo, the Agência Estadual de Recursos Hídricos - AGERH (State Agency for Water Resources) is the institution responsible for ensuring the right to use water resources.

The procedures and technical criteria for obtaining the water allocation in Agência Estadual de Recursos Hídricos - AGERH (State Agency for Water Resources) are established by Iema Normative Instruction Nº 19 of October 4, 2005. For the process formalization, it is demanded the water allocation requirement, forms of interference and purpose of water use, besides the applicant's documents or its legal representative (IEMA, 2005).

In order to build and operate a wet process coffee unit in accordance with the legislation, it is necessary to observe several instruments that standardize the water use, the licensing of the enterprise and the effluent correct destination, in this case, CWW. The standardization are made by federal, state and municipal institutions, through laws, resolutions, deliberations and normative instructions.

CWW is rich in organic matter in suspension and dissolved organic and inorganic compounds, with great potential to pollute the aquatic environment, which is why it can not be released into bodies of standardization without proper treatment. The most notorious effect of CWW release on bodies of water without adequate treatment is fish death. The fast growth of microorganisms that degrade organic compounds of CWW induces high demand for oxygen dissolved in the body of water, limiting the fish respiration and other aerobic organisms, and may cause their death (MATOS, 2008).

The licensing of the coffee processing unit is done by state and municipal environmental institutions and is based on the polluter size and potential. In Espírito Santo, the licensing of coffee wet hulling activity is given by the Instituto de Defesa Agropecuária e Florestal do Espírito Santo - Idaf (Agricultural and Forest Defense Institute of Espírito Santo), according to regulations and procedures established by Idaf Normative Instruction Nº 11, dated October 23 2014 (IDAF, 2014).

The Idaf Normative Instruction Nº 11 considers coffee wet hulling as an activity with high polluting potential and fits it in the simplified classes- S, I or II, according to the hulling capacity, that is, if less than 2,000, between 2,001 to 5,000 and more than 5,000 L of coffee cherries per hour, respectively.

In the case of an enterprise classified in class S, the environmental permit may be issued at the Local Office of Idaf, and the previous inspection of the activity must be carried out. It is necessary to add to the licensing documentation a statement from the City Hall declaring that the activity place and type are in compliance with the legislation applicable to the soil use and occupation in the municipality. The processes related to classes I and II enterprises are sent to the Idaf Environmental Permit Team for licensing (IDAF, 2014a).

The Resolution of the Conselho Nacional do Meio Ambiente - Conama (National Environmental Council) nº 430, dated May 13, 2011, establishes the conditions, parameters, standards and guidelines for the management of effluent releases in receiving water. Article 2 of this resolution states that "effluents from any pollution source may only be released directly into receiving water after proper treatment and provided they comply with the conditions, standards and demands set forth in this Resolution and other applicable regulations" (CONAMA, 2011).

The disposal of effluent in the soil, even treated, is not subject to the release parameters and standards established in Conama Resolution Nº 430, and they can not cause pollution or contamination of surface and groundwater. One of the guidelines contained in the resolution is that sources that pollute water resources should seek efficient water management practices, techniques to reduce generation and, when possible, reuse (CONAMA, 2011).

Based on Conama's resolutions on the release of effluents, state institutions responsible for environmental policy and management can establish specific regulations for the respective states. In Espírito Santo, the CWW must be disposed in the soil following the technical guidelines which are part of the in Idaf Normative Instruction nº 15, dated October 23, 2014. The disposal in the ground can be done by fertigation, subsurface infiltration (percolation trench and/or sink) and runoff on surface ramps. Before being disposed in the soil, the CWW must necessarily pass through a sealed decanter, in order to retain part of the solid material. (IDAF, 2014b).

The CWW destination must be proposed through a technical project, elaborated and presented by a qualified professional. In the fertigation planning, the physical-chemical characteristics CWW and soil and the culture nutritional demands to be fertigated should be considered. In case of percolation trenches or sinks, the difference between the bottom and the water table should be 5 m for clayey soils and 10 m for medium textured soils (IDAF, 2014b).

3 GENERATION OF WASTEWATER IN COFFEE PROCESSING

Most coffee grower harvest at once by mixing green, ripe fruits, raisins and impurities, mainly leaves and branches, which must be manually (Figure 1B) or mechanically removed still in the crop avoiding this material transportation to the unit processing. The harvesting can also be made selectively (manual) (Figure 1A) by selecting only the ripe fruits, which allows to obtain a better quality drink. However, manual harvesting requires a lot of manpower, making this operation much more expensive.

The "farm coffee" is transported to the processing unit and discharged in the hopper (Figure 2A). In most units, coffee is processed in the late afternoon and early evening, on the same day of harvesting. At the base of the hopper, there is an opening with a device for controlling the fruits output (Figure 2B). To control, it is necessary the frequent presence of a person to remove the branches and leaves that obstruct the opening.

Figure 1. Coffee manual harvesting (A); Coffee cleaning still in the field (B).

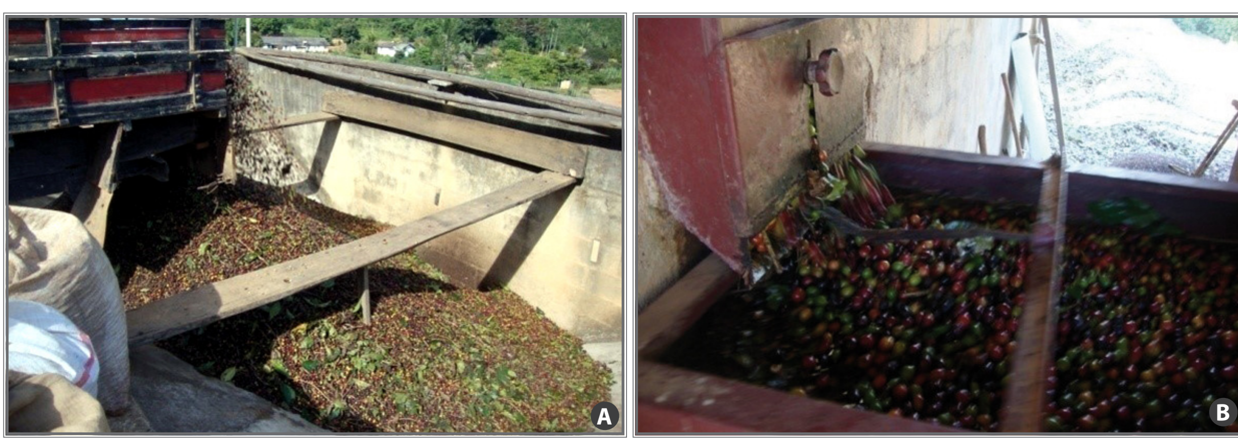

Figure 2. Coffee fruits being discharged in the hopper (A); outlet opening of the hopper (B).

Processing starts with cleaning, when firstly the leaves and light impurities are removed, and sifting (Figure 3), which removes larger and smaller impurities than fruits. In cleaning, no water is used, but if poorly done, leads to more expense in the next operation, the washing, since part of the water remains on the branches and leaves that pass through the washer. The washing, besides removing several dirt, clods and stones, separates the lighter fruits from the heavier ones.

To wash a small portion of "farm coffee", pour it into a water tank. The fruits and impurities less dense than water float- floating coffee - and are removed with a sieve (Figure 4A), while the denser fruits- greens and cherries- sink and are removed later. In mechanical washer, fruits are taken by the water trough a gutter to a compartment with a false bottom in which the green and ripe sink and are driven by an upward flow of water which sends them to the surface in a parallel gutter (Figure 4B), while the fruits float and follow through the same gutter.

Mechanical washers use few water as it is reused in the operation. For this, they have a pump that returns the water during the washing. It is necessary to replace the water that remains on the fruits and impurities surface, as well as to replace that of the washer, resulting in an expenditure of 0.1 to 0.2 L of water per liter of coffee fruits (MATOS, 2008). A survey carried out in the southern regions and Zona da Mata of the State of Minas Gerais found that 54% of coffee farms spend less than 1 L of water per liter of fruit, 38% spend from 1 to 5 L and 8% spend more than 5 L (VILELA, RUFINO, 2010), in the latter case, using manual washers.

Figure 3. Coffee mechanical cleaning and sifting.

Figure 4. Washing in water boxes and floating coffee removal with sieve (A); separation of floating coffee from the green and cherry ones in the mechanical washer (B).

In most processing units, the fruits transportation from the washer to the huller is done by water, requiring a considerable portion of what is spent on hulling, estimated in a volume of 3 to 5 L per liter of fruits (MATOS, 2008). The expense can be decreased if the washer is installed so that the nozzle through which the greens and cherries are output is placed at the fruit entrance into the huller by cutting/landfill into the ground or construction of support structure for the washer. Another option is to make the transport mechanically through elevators.

In the huller's cylinder, the fruits are pressed against a sieve (Figure 5A) and the skin of the ripe fruit breaks, releasing the beans - peeled cherry coffee - that pass through the sieve, together with the skin, while the green fruits do not pass and are output through a side nozzle. A multi-orifice tube - nozzle - throws water over the huller cylinder to facilitate the movement of fruits, beans and skin (Figure 5B).

In order to facilitate the management of peeled cherries, it is common to remove part of the mucilage that sticks to the beans in the demucilator (Figure 6A) or degumming tank (Figure 6B). In the pulping machine, the beans enter the base, in a cylinder with a rough internal axis that raises the beans to the top, from where they leave. During the displacement, the mucilage is removed by means of water flowing through the cylinder. In degumming, the beans are kept in a tank, immersed in water; the mucilage is hydrolyzed and consumed by microorganisms.

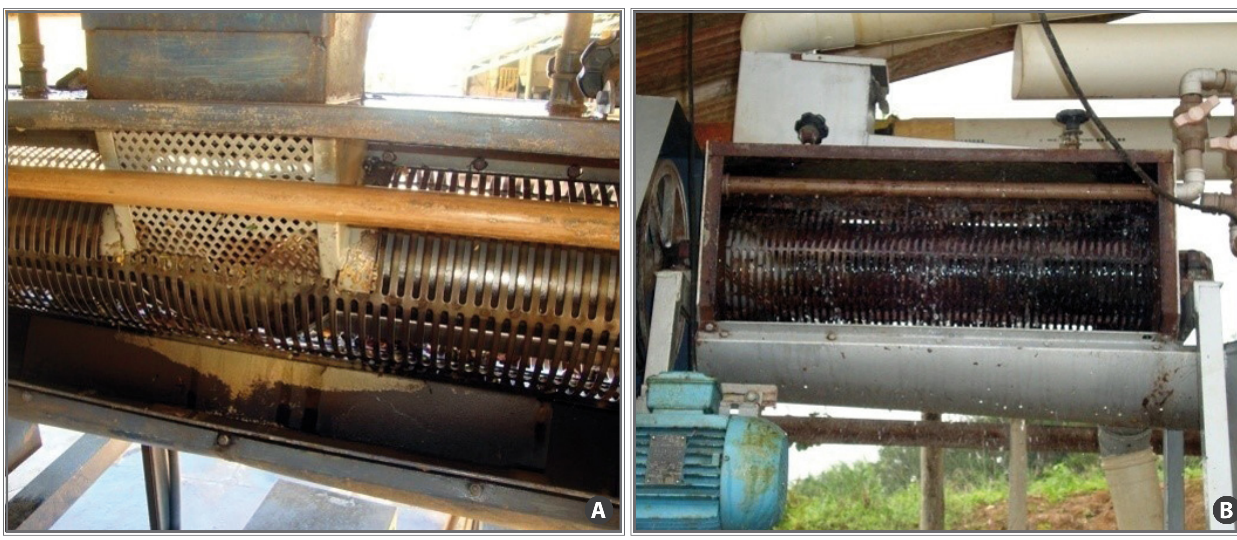

Figure 5. Huller cylinder (A); tube with holes to throw water- nozzle- onto the huller cylinder (B).

Figure 6. Pulping machine A); degumming tank (B).

4 COFFEE WASTEWATER CHARACTERIZATION

Water is the element that leads the fruits though the processing unit and several residues are joining it along the path, such as: fragments of branches, leaves and dirt that are on the coffee skin in the wash; parts of the fruit, such as the peduncle and the crown, skin fragments and part of the mucilage, in the hulling; part of the mucilage, in the degumming and pulping; clumps and stones, when coffee is collected from the ground (SOARES et al., 2007). Mucilage is composed of sugars, proteins and fibers, constituting an excellent substrate for the growth of microorganisms involved in fermentation, accelerating this process (BORÉM, 2008).

The CWW's solid material is suspended or dissolved, being the most part volatile, and its organic load, estimated by biochemical demand BOD and oxygen chemistry - OCD, reaches 29,500 and 14,340 mg.L^{-1}, respectively (MATOS; LO MONACO, 2003). CWW biochemical analysis carried out by Campos, Prado and Pereira (2010) (2010) found the presence of sugars (44,667 mg.L^{-1}), starch (1,067 mg.L^{-1}), pectin (1,315 mg.L^{-1}), phenolic compounds (1,212 mg.L^{-1}) and protein (0.44%).

The compounds present in the CWW contain several elements such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), zinc, boron (B), copper (Cu), and manganese (Mn), reason why several authors propose its use as a source of nutrients and organic matter for the cultures (LO MONACO, 2005; MATOS, 2008; SOARES et al., 2008).

Garcia et al. (2008) analyzed wastewater samples from the processing of conilon coffee fruits generated in fruit washing (E1); in hulling(E2); in hulling by re-using the effluent E2 in the huller (E3); in the hulling process by reusing E3 (E4) effluent. Table 1 shows the analyzes results. It was observed that the washer effluent had less solid waste than the huller effluents and that the organic load increased with the effluent reuse. In order to be discharged into bodies of water, any of the analyzed effluents should be treated in accordance with Conama Resolution 430.

Table 1. Physical-chemical characteristics of the wastewater generated in the processing of conilon coffee fruits

(to be continued)

Characteristics	**Effluents**			
	E1	**E2**	**E3**	**E4**
pH	**4.9**	**4.7**	**4.1**	**4.1**
Electrical conductivity (dS m^{-1})	0.25	0.58	0.72	0.99
Sedimentable solids (mg. L^{-1})	17	< 1	180	330
Total solids (mg.L^{-1})	1069	4889	5504	6403
Suspended solids (mg.L^{-1})	380	850	1888	2336
Dissolved solids (mg.L^{-1})	689	4039	3616	4067
Total fixed solids (mg.L^{-1})	390	126	706	848
Total volatile solids (mg.L^{-1})	679	4763	4798	5555
BOD (mg.L^{-1})	1520	5148	10667	11000
COD (mg.L^{-1})	411	2525	3184	3374

(conclusion)

Characteristics	Effluents			
	E1	E2	E3	E4
pH	**4.9**	**4.7**	**4.1**	**4.1**
Total nitrogen (mg.L^{-1})	76.8	105.5	124.6	160.0
Total phosphorus (mg.L^{-1})	5.0	8.8	10.8	13.9
Sodium (mg.L^{-1})	25.5	45.0	58.3	77.1
Potassium (mg.L^{-1})	41.0	115.0	153.7	204.7

Source: Garcia et al. (2008).

E1- washer effluent; E2- huller effluent; E3- huller effluent, with reuse of E2 effluent; E4- huller effluent, with reuse of E3 effluent.

Analyzes of CWW samples collected from 40 properties in the arabica coffee producing region of the State of Espírito Santo presented a wide range of nutrient concentrations (Table 2). This range was due to CWW collection in different stages of the hulling/pulping process and the volume and number of water recirculation in the processing unit. The nutrients found in larger amounts were K and N. The relation between Ca and Mg contents approached 3: 1 and B was the element found in smaller quantities, preceded by Cu, Zn and Mn (PREZOTTI et al., 2012).

Table 2. Maximum, minimum and average nutrient contents in wastewater samples collected in waste ponds at forty properties in the arabica coffee producing region of Espírito Santo

Nutrients limits	N	P	K	Ca	Mg	Cu	Zn	Mn	Fe	B
	mg/L									
Maximum	205	23	875	94	28	40	44	80	28	12
Minimum	1,5	1	1,5	1	1	1	1	1	0,3	1
Average	106	5	225	30	9	2	3	5	31	1
Standard-deviation	63	6	202	22	8	11	12	22	127	4
CV (%)	60	137	97	73	83	459	444	447	406	366

Source: Prezotti et al. (2012).

CWW samples collected during and at the end of the processing journey in different processing units of the region of Viçosa/MG and carried on the same day for laboratory analysis presented nutrient concentrations much higher than those reported by Prezotti et al. (2012) and also varied a considerably (Table 3). In two of the samples, the concentration of N was higher than that of K (SOARES et al., 2009).

Table 3. Nutrient contents in samples of arabica coffee wastewater collected in different processing units

Sample	Nutrient contents in wastewater samples in mg. L^{-1}								
	N	P	K	Ca	Mg	Cu	Mn	Fe	Zn
1	317	102	373	34	7.2	0.35	0.48	9.40	0.07
2	550	12	317	31	6.3	0.60	ND	4.50	ND
3	159	11	90	11	4.0	0.13	ND	0.09	0.37
4	1194	100	410	413	14.5	0.83	14.3	8.20	7.10
5	167	11	983	186	9.5	0.88	0.21	3.73	1.47
6	112	5	175	323	22.3	-	0.43	7.72	2.57

Source: Soares et al. (2009).

Moreli (2013) carried out the processing of arabica coffee by reusing the CWW over a period of five days. Table 4 shows the results of the nutrient contents analysis after the first, second, third, fourth and fifth days of processing. It is possible to observe that nutrient contents increased during the processing period, especially between the first and second day.

Table 4. Nutrient contents in wastewater after 1, 2, 3, 4 and 5 days of reuse in the processing unit

Day	N	P	K	Ca	Mg	S	Zn
	mg.L^{-1}						
1	177	14	441	41	10	10	0.80
2	394	31	1031	70	22	24	2.03
3	393	37	1185	77	25	26	1.89
4	455	45	1316	99	26	32	1.85
5	483	48	1384	101	34	34	1.66

Source: Moreli (2012).

5 WASTEWATER REUSE

As already mentioned in the introduction, the processing of peeled cherry coffee consumes a lot of water and generates CWW, rich in organic material, with potential to pollute the environment. In order to process one liter of coffee fruits, about 3 to 5 L of water are spent (MATOS, 2008) and to produce a bag of processed coffee, 450-500 L of fruits are spent (MALTA; CHAGAS; CHALFOUN, 2008). Considering these relation, it is possible to deduct that in order to obtain a bag of processed coffee, from 1,350 to 2,500 L of water are spent.

One of the guidelines for the effluents management that are part of Conama Resolution 430 is that "potentially or actually polluting sources of water resources must seek practices that look for the efficient use of water, the application of techniques to reduce generation and improve the quality of generated effluents and, when possible and appropriate, to reuse "(CONAMA, 2011).

The reuse of CWW in processing is an option to reduce water consume, especially in older units, which operate with traditional equipment. To reuse the CWW, it is necessary to pump into a reuse box (Figure 7A) located upstream of the unit, which allows regulating the inflow into the huller. In some processing units, the CWW is pumped from the settling tank into the reuse box (Figure 7B). In this case, only residues that are denser than water are removed; the lighter ones and those with density close to the water density are not removed and can clog the nozzle of the huller (Figure 8A).

There are in the market machines of various brands, called filter, separator or regenerator, which have a fine mesh sieve capable of removing very small impurities (SOARES et al., 2012). In many processing units, these machines are positioned before the settling tank (Figure 8B), strangling the CWW flow. This can be avoided if the filter, separator or regenerator is positioned after the settling tank, since much of the waste would have already been removed, thus avoiding obstruction of the sieves mesh.

Figure 7. Wastewater reuse box (A); pumping of the settling tank for reuse (B).

Figure 8. Nozzle with clogged holes (A); solid waste filter (B).

5.1 WASTEWATER CLEANING SYSTEM

A system of waste disposal, called “wastewater cleaning system” - WWCS, consisting of boxes and sieves, which associates the decantation and sieving processes and can be built on the property, was developed by Embrapa Cafe, a participant of the Empresa Brasileira de Pesquisa Agropecuária - Embrapa (Brazilian Agricultural Research Corporation) structure, in partnership with the Empresa de Pesquisa Agropecuária de Minas Gerais - Epamig (Agricultural Research Company of Minas Gerais) and the Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural - Incaper (Capixaba Institute for Research, Technical Assistance and Rural Extension) (SOARES et al., 2012; SILVA, 2015). The WWCS is composed of three 1,000 L settling tanks, interconnected by 100 mm PVC pipes (Figure 9A), and two cylindrical sieves, the first with 1.51 mm mesh opening and the second of 1.00 mm, both 1 m in length and 0.22 m in diameter, arranged inclined after the water exit from the third tank (Figure 9B).

The CWW generated in the processing unit enters through the upper part of the first tank and flows to the following through the L-shaped PVC pipes, which collect the water at 0.30 m from the bottom of the preceding box. Such tubes are essential to remove impurities that are less dense than water, which float and are retained on the boxes surface, while the denser impurities decants at the bottom. After passing through the settling tanks, the CWW passes through the sieves, falls into a tank and is pumped into the reuse box to be reused. The sieves remove impurities big enough to cause the clogging of the huller nozzle. Silva (2014) has published in the media a film showing how WWCS works.

Figure 9. Settling tanks (A); sieves of the wastewater cleaning system (B).

5.2 EXPERIMENTS WITH THE CLEANING SYSTEM

The WWCS was evaluated in an experiment conducted by Moreli (2010) at the Incaper Experimental Farm, in Venda Nova do Imigrante/ES. Table 5 shows the time interval between the beginning and the end of the processing, the amount of fruits processed and the water consumption in the four repetitions of the experiment.

Table 5. Processing length (PL), volume of water consumed (WC) and processed fruit (PF)

Repetition	PL	WC	PF	WC/PF
	min	L	L	L/L
1	144	5053	9250	0.53
2	151	5213	10240	0.51
3	155	5136	10460	0.49
4	142	5179	9200	0.56
Average	148	5145	9855	0.52

Source: Moreli (2010).

The consumption at the beginning of the processing, before reusing the CWW, was 2.2 L of water per liter of fruits. The processing lasted 142-155 minutes, time enough for the water to be reused four times in the unit, without clogging, proving the WWCS functionality. 0.52 L of water per liter of processed fruits were consumed on average, significantly below the 3 to 5 L mentioned in the literature (MATOS, 2008) and 76% less than the initial consumption. The sensory evaluation did not detect a difference in the beverage originated from the cherry coffee peeled with clean or reused water (MORELI, 2010).

In another experiment, Moreli (2013) carried out the arabica coffee processing by reusing the CWW over a five days period. The consumption at the beginning of the processing, before reusing the CWW, was 1.96 L of water per liter of fruits, 11% lower than that obtained in 2010. This performance was attributed to the decrease between the washer and the huller and the greater inclination of the gutter that leads the fruits between such machines.

The amount of water spent decreased during the processing journey, reaching a minimum of 0.278 L of water per liter of fruit on the fifth processing day (Figure 10). In sensory evaluation, carried out according to the Associação Americana dos Cafés Especiais - SCCA (American Association of Special Coffees) protocol, no significant differences were detected between the beverages originated from the coffees processed over the days (Table 6). The final grades were higher than 80 points, which, according to the SCCA methodology, allows to classify beverages as excellent (MORELI, 2013).

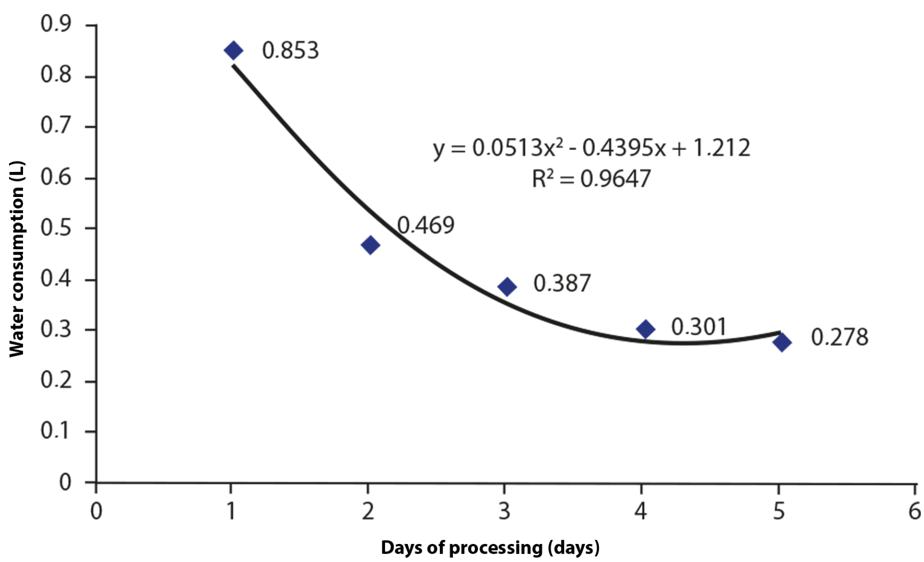

Figure 10. Water consumption (liters of water/liter of processed fruits) over five processing days.
Source: Moreli (2013).

These results indicate that the proposition of adjustments in the unit in order to make the reuse of the CWW in the processing possible, is an interesting coffee grower's strategy in their businesses management and a strong ally to make the enterprise environmentally viable with regard to the water allocation and in the environmental permit, since the reuse of CWW has become a condition of these processes (REIS et al., 2013).

Table 6. Organoleptic properties of the beverage originating from processed coffee with wastewater for 1, 2, 3, 4 and 5 processing days

Days	Organoleptic properties						Final Result
	Aroma	Flavor	Acidity	Body	Balance	Finishing	
1	7.222	7.194	7.139	7.180	7.250	7.194	80.530
2	7.375	7.305	7.181	7.208	7.153	7.180	80.628
3	7.375	7.264	7.167	7.208	7.222	7.139	80.419
4	7.222	7.319	7.242	7.242	7.278	7.333	80.983
5	7.375	7.247	7.194	7.250	7.222	7.305	80.858

Source: Moreli (2013).

6 WASTEWATER DESTINATION

To be disposed into a body of water, the CWW needs to be treated in order to meet the conditions and standards set by the legislation. The treatment is complex and requires the involvement of a qualified professional to plan and guide the construction of the necessary structure, as well as to monitor the CWW physical and chemical characteristics in order to meet the legal demands.

In the preliminary treatment, the bigger solids present in the CWW are removed, such as leaves and branches; followed by the primary treatment in which part of the suspended solids are removed by decantation and another part by anaerobic degradation; the secondary treatment completes the degradation process of the suspended organic matter, performed by the microorganisms present in the wastewater.

Several equipment and structures, such as sieve, filter, settling tank, anaerobic pond and facultative lagoon are used to make the CWW treatment. A description of such structures and examples of how to measure them can be found in the Technical Bulletin published by the Federal University of Viçosa, which also includes methods of CWW disposal in soil, ditches, ramps and through fertigation, in addition to treatment in flooded areas (MATOS; LO MONACO, 2003).

The CWW treatment is uncommon in the properties that perform the processing of the coffee tree fruits due to the high cost and the lack of qualified labor to control the treatment process. In most cases, the CWW generated in the processing unit is collected in a settling tank (Figure 11A) and then pumped and disposed in ditches or infiltration basins (Figures 11B and 11C).

Figure 11. Settling tank (A); percolation trench (B); and infiltration basin(C).

In the state of Espírito Santo, the legislation allows the CWW to be disposed in percolation trenches and sink. To minimize the risk of groundwater contamination the bottom of the trench must keep a minimum vertical distance of 5m or 10m for clayey or medium textured soils, respectively. CWW disposal is not allowed under conditions of sandy or high permeability soils

(IDAF, 2014b). The standard does not mention the distance of trenches in relation to surface bodies of water, such as springs and/or waterways, but care must be taken to ensure that these bodies are not contaminated.

The percolation trench measure is done in accordance with the volume of CWW that is generated in the processing and the basic infiltration rate (BIR) of the water in the soil. There are several methods for determining BIR using clean water for this purpose. However, the CWW contains residues that cause the soil to become clogged, obstructing the porous space, which reduces the infiltration rate, reason why BIR correction factors are used.

Matos and Lo Monaco (2003) suggest the infiltration basin method as the best option for determining the BIR and cite that it is common to adopt a correction factor of 10 to 15% to calculate the area required to dispose the CWW using the equation:

$RA = Q.BIR^{-1}.F_p^{-1}$, where:

RA - required area, in m^2; Q - quantity of wastewater generated per day, in m^3d^{-1}; BIR - basic infiltration rate, in $m.d^{-1}$; F_{p} - project factor, between 0.10 and 0.15.

NBR 13969/97 regulates the construction of percolation trenches for final disposal of effluent from septic tanks (ABNT, 1997). Some of the criteria that are part in this regulation could be adapted for the CWW destination. This regulation establishes that the rate of soil percolation is used in the sizing of the percolation trench, describes a simple procedure to determine the rate of percolation and recommends the minimum vertical distance of 1.5 m between the bottom of the trench and the water table. For the purpose of calculating the infiltration area, the lateral and bottom areas of the trenches are considered (ABNT, 1997).

It is common to find cases of processing units, in which the percolation trenches were oversized. One strategy for suiting the sizing is to build the trenches in stages. Before the processing unit starts working, two trenches, A and B, are interconnected on the surface by furrows or tubes, each of them able of storing the CWW to be generated in one day.

When the processing unit comes into operation, direct the CWW from the first day to trench A and, at the end of the processing journey, mark the CWW level in that trench. On the following day, before starting the processing, measure the difference comparing it with the previous day numbers, the time elapsed and, during processing, once again direct the CWW to the trench A; the excess will pour into the trench B. At the end of the journey, mark the level in the trench A and B. On the third day, measure the difference in relation to the previous day and the interval elapsed.

The observed infiltration will allow us to decide whether to build additional trenches to accommodate the CWW to be generated on the third day of processing or whether this can be done later. Over time, the infiltration rate decreases until it becomes less variable, and the sizing of the trenches to accommodate the CWW can be adjusted for each situation.

7 EFFECTS OF THE WASTEWATER APPLICATION ON THE SOIL

Garcia et al. (2008) applied the CWW from the washing and depulping of conilon coffee fruits in vases with dirt collected in three soil categories. The vase were saturated with a mixture of clean water and CWW, in five different proportions. After 20 days of incubation, they found that K content, pH, base saturation and "cation exchange capacity" (CEC) increased with increasing CWW concentration, while aluminum saturation decreased.

Prezotti et al. (2012) conducted a greenhouse experiment, applying increasing doses of CWW on 2 dm^3 of a soil classified as Red-Yellow Latosol, characteristic from the arabica coffee producing region in the State of Espírito Santo. Table 7 presents the nutrient contents of the CWW used in the experiment, and it can be observed that K, followed by N, were the nutrients present in higher concentration.

Table 7. Nutrient contents of wastewater

N	P	K	Ca	Mg	Cu	Zn	Mn	Fe	B
mg. L^{-1}									
90	7	280	30	11	0.1	0.2	0.3	6.7	0.2

Source: Prezotti et al. (2012).

The wastewater application in the soil increased the pH and the contents of P, K, Na, Ca, Al, Zn and organic matter, also raising the saturation by V- bases (Figure 12). Based on the equation declivity of regression, we observed that, on average, there was an increase of 0.078 pH unit for every 10 L of wastewater applied per m^2 of soil. This increase is significant and indicates that it is necessary to monitor the pH through soil analyzes to avoid that it rises much with successive applications.

K was the element that presented the highest elevation rate, calculated at 11.4 $mg.dm^{-3}$ of K for each 10 L of CWW applied per m 2 of soil. There was an increase of 0.42 $mg.dm^3$ of P for every 10 L of CWW applied per m^2 of soil. The organic compounds, besides presenting P in their constitution, block the P adsorption sites, making it more available (ANDRADE, 2004).

The contents of Na and Ca increased in the rate of 0.57 $mg.dm^{-3}$ and 0.03 $cmol_c/dm^3$, and the Al content decreased in the rate of 0.08 $cmol_c/dm^3$ for every 10 L of CWW applied per m^2 of soil, respectively. The reduction of Al^{3+} availability may occur due to its lower solubility, the pH increase and its complexation by organic acids (SILVA; MENDONÇA, 2007). Among the micronutrients, Zn presented a significant increase in its content with the application of CWW, with an increase of 0.07 $mg.dm^{-3}$ for every 10 L of CWW applied per m^2 of soil.

The application of CWW increased the organic matter content of the soil, following a quadratic trend (Figure 12). This increase is important, mainly when considering the low organic matter content of most soils in the coffee producing region of the State of Espírito Santo.

It is highlighted that the organic matter contained in the CWW needs to pass through the mineralization process, which is done by soil microorganisms that for this, require nutrients, mainly N. For this reason, the accumulation of CWW in places close to the plants roots, besides the problem of oxygen deficiency caused by waterlogging, can cause nutritional deficiencies by competition with soil microorganisms, in extreme cases, cause irreversible damages to plants. Thus, the system of CWW application in the crops should allow a homogeneous distribution on the soil surface, avoiding the formation of puddles and also the superficial runoff.

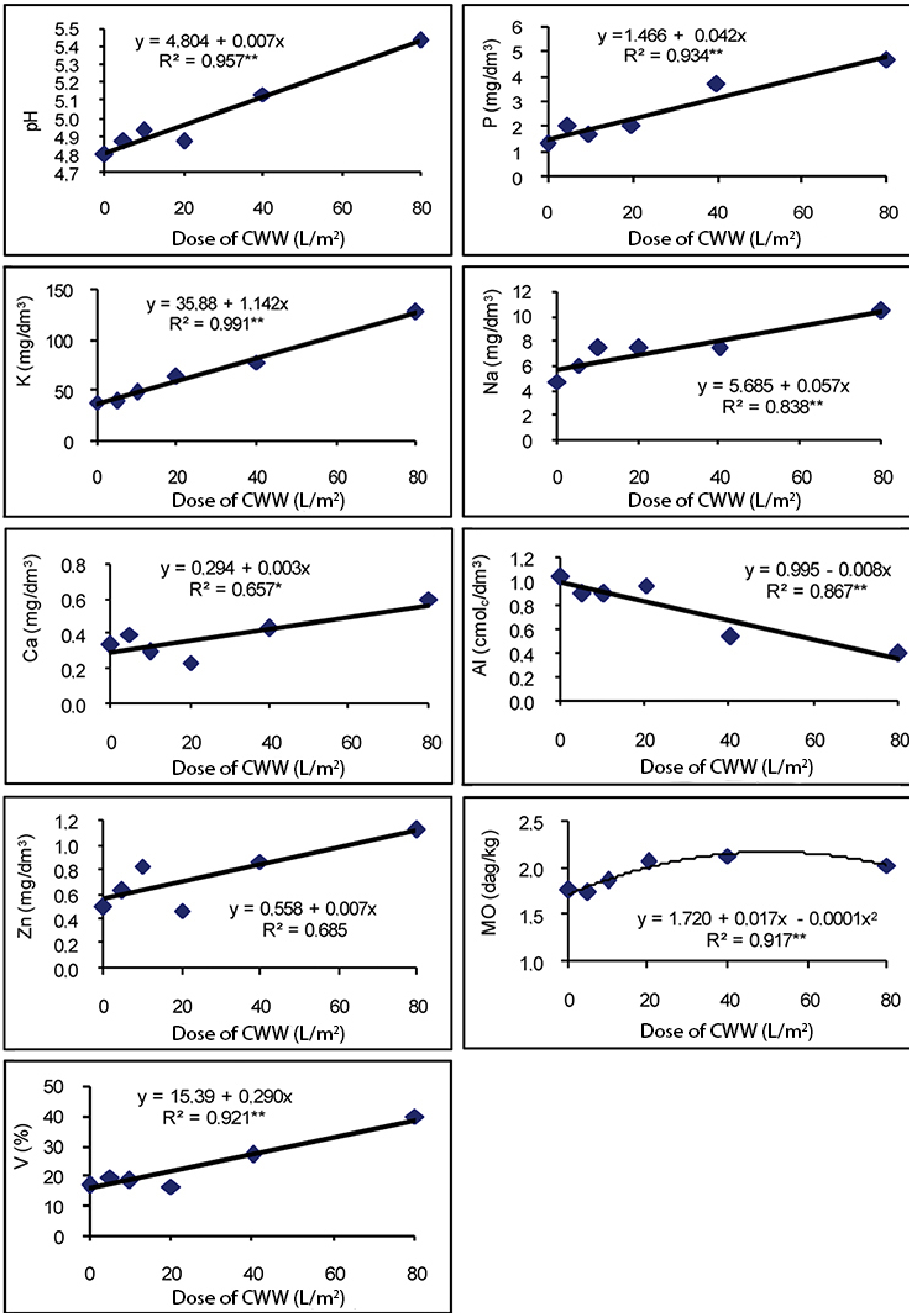

Figure 12. pH variation of P, K, Na, Ca, Al, Zn, organic matter (OM) and base saturation of the soil (V) related to the application of increasing doses of wastewater.

Source: Prezotti et al. (2012).

Soares et al. (2010) applied doses of 0, 250, 500, 1,000, 2,000 and 4,000 ml of CWW in vases with 5 L of substrate and, 30 days later, planted black oat, which was harvested at the time of flowering. The K contents of the substrate rose with increasing CWW rates, while P, Ca, Mg contents and substrate pH levels were not affected (Table 8). Lo Monaco et al. (2009) used the CWW in coffee fertigation at doses corresponding to 0, 2, 3, 4, 5 and 6 times the recommended K necessity for the crop (80 g.furrow^{-1} of K_2O). The application of CWW was divided in order to complete the dose in a period of 2 months. The pH, the electrical conductivity (EC) and the concentrations of macro and micronutrients in the soil, in the layers of 0 to 20, 20 to 40, 40 to 60 and 60 to 80 cm of depth were evaluated. The pH, EC, and K concentration in the soil profile rose with increase of CWW dose. The K excess provided Ca leaching and, mainly, of Mg in the soil profile, reducing the availability and causing the deficiency of these nutrients in the leaves of the coffee tree. There was an increase in the concentration of Fe, Mn and Cu and reduction of Zn with the CWW application.

Table 8. Substrate chemical characteristics with the application of different doses of wastewater from coffee processing

Doses mL	pH	P	K	Ca	Mg	CEC	V	OM
		mg.dm^{-3}			cmol$_c$.dm^{-3}		%	dag.kg^{-1}
0	5.97	31	113	3.0	1.50	4.8	64	2.20
250	6.20	29	155	2.9	1.50	4.8	68	2.42
500	6.02	28	158	2.8	1.40	5.6	66	2.17
1000	6.07	28	217	2.9	1.47	4.9	68	2.15
2000	6.05	25	335	2.9	1.42	5.2	68	2.17
4000	6.42	25	542	2.9	1.47	5.8	75	2.32

Source: Soares et al. (2010).

8 EFFECTS OF WASTEWATER APPLICATION ON PLANTS

In an experiment carried out in vases containing 2 dm^3 of a soil classified as Red-Yellow Latosol, in a greenhouse, Prezotti et al. (2012) applied the doses of 0, 5, 10, 20, 40 and 80 Lm^{-2} of CWW in the soil. After 30 days of incubation, samples were taken for soil analysis and corn was sown and harvested one month later. It was observed a sharp increase in biomass production of corn plants (Figure 13) at the dose equivalent to 5 Lm^{-2} of CWW when compared to the original seeds. At the following doses, lower biomass increments were observed, and the dose responsible for the maximum physical production was 57 Lm^{-2}, calculated on the basis of the regression equation:

$y = 29.378 + CWW + CWW^{-0.5}$ (R2 = 0.93), where:

y is corn biomass and CWW is the dose of wastewater applied.

The K levels in the aerial part of the plants rose with the increase of the dose of applied CWW, with a linear tendency in the order of 0.156 dag.kg^{-1} for every 10 Lm^{-2} of CWW (Figure 14). It was not observed an increase of the other macro and micronutrients contents in the aerial part of corn plants, probably due to the phenomenon called "dilution effect", which usually happens in the initial phase of plant development. In this case, due to the greater plants development, provided by the application of CWW, the tissue formation rate was higher than the nutrient absorption rate.

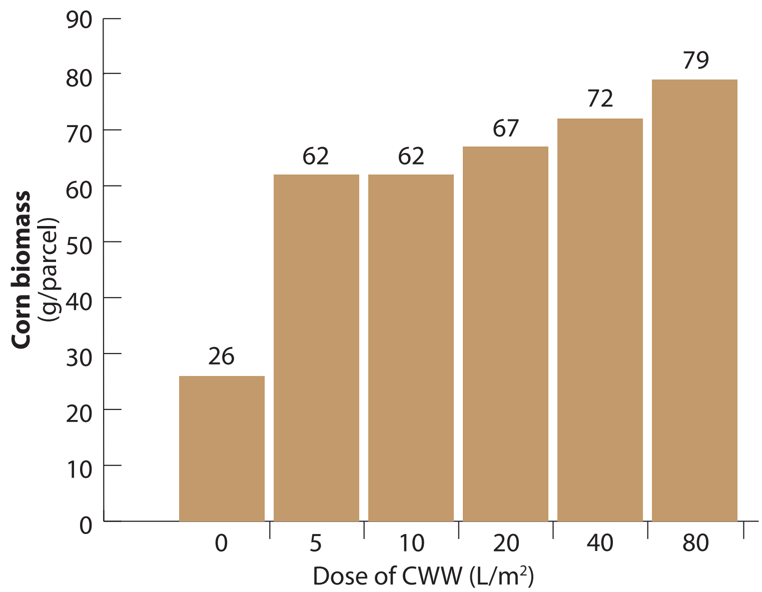

Figure 13. Biomass production of corn plants as a function of wastewater doses.
Source: Prezotti et al. (2012).

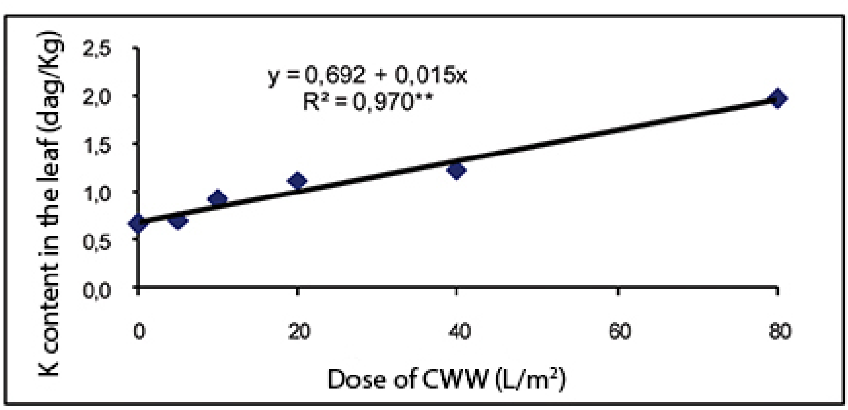

Figure 14. K content in the aerial part of corn plants related to doses of coffee wastewater.
Source: Prezotti et al. (2012).

Soares et al. (2010) applied CWW on corn leaves, at doses 0, 50, 100, 150, 200, 250, 300 and 350 mL per plant, in six occasions. The corn was grown in cement tanks with 1,000 L of soil, and the CWW was applied in intervals of one week, from the seventh day of plants emergence. The dry mass of the stem, leaves and corn plants was not altered with the application of CWW doses, while K leaf contents increased and Ca and Mg decreased with higher doses (Figure 15). No scorching symptoms were observed on corn leaves.

In another experiment with corn, under greenhouse conditions, Soares et al. (2011) applied

CWW at doses 0; 0.14; 0.28; 0.56; 1.12 and 2.24 L. vase^{-1}, with 6 L of soil and sowed corn 70 days later. The CWW application did not affect height, while the base diameter and dry mass of the aerial part of the plants increased linearly with the higher dose. The CWW application did not cause scorching on corn plants.

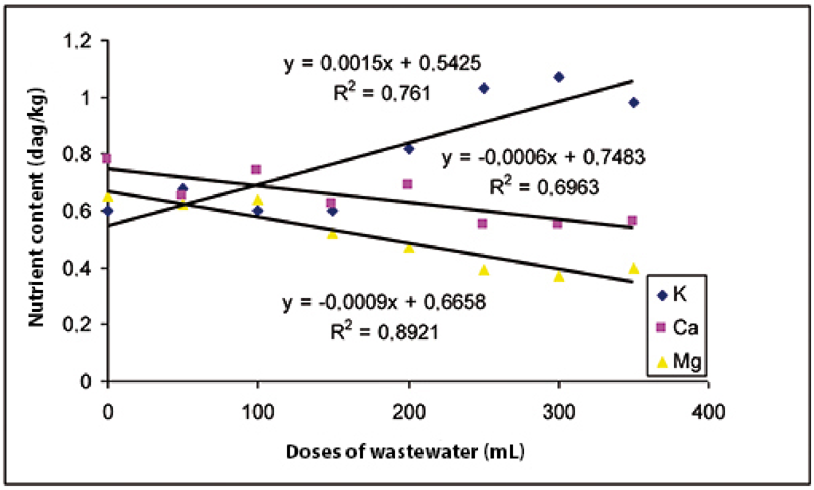

Figure 15. K, Ca and Mg contents in corn leaves with the application of different doses of wastewater from coffee processing.

Source: Soares et al. (2011).

Soares et al. (2009) applied CWW on lettuce leaves at doses 0, 50, 100, 150, 200 and 250 mL, in four occasions, in one week intervals. No leaf scorching symptoms were observed, however, the plants and leaves dry mass decreased with the higher dose of wastewater, while the K contents in the leaves were not affected.

In a test and validation unit installed in a coffee farm, the CWW was applied on the coffee leaves, with watering can, at the dose of 40 L per plant. The CWW application did not alter the nutrient content and no scorching symptoms were observed on the plants leaves (SOARES; DORNELES, 2011).

9 WASTEWATER USE IN COFFEE CROPS

The CWW contains elements such as N, P, K, Ca and Mg, which can be used for plant nutrition, as well as organic matter, which can improve soil physico-chemical and biological conditions. Besides improving fertility conditions, the use of CWW in the soil contributes to increase the productivity and improve the quality of harvested products, as well as reduce the risk of environmental pollution (MATOS; LO MONACO, 2003; LO MONACO, 2005; MATOS, 2008).

9.1 WASTEWATER DOSE TO BE APPLIED

CWW doses should be planned with the purpose of providing nutrients to the crops, not to attend the plants water needs, when it could happened the excess of some nutrients, especially

K. As Tables 1, 2, 3 and 4 show, in most cases, K is the element found in larger amounts in the CWW samples.

In order to calculate the dose to be applied, it is essential to have the analysis data of CWW, since the contents are very variable, especially if the harvesting is in the beginning, middle or end, and whether the processing unit reuses CWW or not. This implies that the analysis should be repeated throughout the harvesting for a more accurate reference.

The dose estimate to be applied in the soil can be made based on the CWW K content. To avoid the K leaching caused by excessive doses, it is possible to use the saturation method by K in soil CEC_{pH7}, which has as a principle the increase of current K saturation of the soil up to a maximum of 5%, number considered suitable compared to the other cations in the CTC_{pH7} of the soil.

As an example, in a soil with K saturation at CEC_{pH7} equals to 2%, a K dose equivalent to 3% of its CEC reaching, thus, the maximum saturation of 5% of the CTC_{pH7} of the soil. Considering a soil with CEC_{pH7} equals to 6 $cmol_c$ and dm^{-3}, a dose equivalent to 3% of 6 cmol and dm^{-3} could be added resulting in 0.18 $cmol_c$ and dm^{-3} of K or 70.2 $mg.dm^{-3}$ of K. Assuming that the CWW has a K content of 250 $mg.L^{-1}$, a dose of 0.28 L dm^{-3} or 560 $m^3.ha^{-1}$ should be applied to provide 70.2 mg. dm^{-3}.

To determine the CWW dose be applied, the following formulas may be used:

$SK_C = (TK_S/390/CEC) \times 100$

$WD = \{[(5-SK_C)/100 \times CEC \times 390]/K_A\} \times 2000$, where:

SK_C = potassium saturation (%);

TK_S = K content in the soil ($mg.dm^{-3}$);

CEC = soil potential CEC determined at pH 7 ($cmol_c$ dm^{-3});

WD = dose of coffee wastewater, in $m^3.ha^{-1}$;

K_A = K content in the coffee wastewater (mg. L^{-1}).

Soares et al. (2013) applied 0, 25, 50, 75 and 100% of the calculated CWW dose to raise the saturation by K at CEC of soil to 5%, equal to 200 m^{-3} ha^{-1}. The K levels of the soil and CWW were 41 $mg.dm^{-3}$ and 710 $mg.L^{-1}$, respectively, and the CEC was 5.75 $cmol_c$ dm^{-3}. Using these data and the formulas mentioned above, the dose to be applied, equal to 200 $m^3.ha^{-1}$, was determined. The CWW was applied on the leaves of seven-month-old coffee plants. Fifteen days after application, soil and leaves samples were collected to determine the chemical characteristics.

No significant effects of treatments on soil pH, CEC and V, and on K, Ca and Mg contents in the leaves were observed. The K content in the soil rose with a higher CWW dose, however, it did not reach the 5% CEC limit (Table 9). The rise of K content to the 5% limit of CEC is a criterion that can be adopted when calculating the CWW dose to be applied in crops fertigation. The wastewater application did not cause damages in the coffee plants (Figure 16).

Figure 16. Wastewater application (A); coffee plants aspect two weeks after the wastewater application (B).

Table 9. Potassium content (K_S), pH, cation exchange capacity at pH 7.0, soil base saturation index and potassium (K_f), calcium and magnesium contents in coffee leaves with increasing doses of wastewater

Dose Lm^{-2}	Ks	pH	V	CTCT	Kf	Ca	Mg
	$mg.dm^{-3}$		$cmol_c.dm^{-3}$		$dag.kg^{-1}$		
0	44	4,50	29	7.59	1.35	0.85	0.24
5	61	4.28	23	8.22	1.29	0.80	0.27
10	63	4.68	29	8.07	1.41	0.81	0.26
15	74	4.48	32	8.22	1.35	0.91	0.28
20	92	4.32	26	10.21	1.35	0.73	0.23

Source: Soares et al. (2013).

9.2 WASTEWATER METHOD OF APPLICATION

The method of application panning is done based on the amount of CWW that is generated and will be used. A unit that processes 200 portions of 60 L of fruits totaling 12,000 L, and spends 3 L of water per liter of fruits, generates 36 m^3 of CWW per day. If this unit adopts the reuse procedure, the consume can be reduced to 0.8 L of water per liter of fruits, generating 9.6 m^3 of CWW per day.

In the case of coffee, CWW can be applied superficially, in furrows built between the plants lines, in flat areas or in sloping areas, in which planting has been performed in contour lines (Figure 17A). Assuming that the dose is 200 $m^3.ha^{-1}$, as in the case of Soares' et al. research (2013), mentioned in item 7.1, and that the spacing between lines is 3 m, it would be applied 0.06 m^3 of CWW per meter of furrow. Assuming that the processing unit generates 9.6 m^3 of CWW per day, this volume could be used in 160 m of furrow and it would be necessary to operate 20 days to produce the amount of CWW to apply in 1 ha.

Figure 17. Coffee wastewater application in furrows (A); sugarcane wastewater application with water cannon (B).

If the processing unit is positioned upstream of the area to be fertigated, the CWW conduction to the furrows can be done from the CWW receiving box or tank of the unit itself. If the positioning is downstream, a hydraulic pump will be necessary to pump the water to a box positioned in order to facilitate the CWW conduction to the furrows. For a more uniform CWW distribution, the furrows should be subdivided with dirt barriers every 10 - 15 m.

The CWW can be applied by tank-cart that are used for the application of liquid fertilizers, pulled by a tractor. These carts are equipped with spreader nozzles, which make it possible to apply superficially, between the plants lines, in flat or low slope areas, or by spraying, in bands involving several lines simultaneously, in flat or sloping areas. In this case, the application can be made by the carriers. The CWW can also be applied with the use of a hydraulic cannon (Figure 17B), by sprinkling, in circles with a radius of application ranging from 30 to 100 m.

The CWW should be applied to the soil surface in a homogeneous manner, in order to avoid the formation of puddles close to the plants. This could cause O_2 *deficit* due to waterlogging and soil salinization by nutrients excess. During the application, surface runoff should be avoided not to cause erosion and possible contamination of bodies of water located near the fertigated area.

10 FINAL CONSIDERATIONS

The coffee fruits processing makes it possible to obtain the peeled cherry coffee, a product with a differentiated value in the market; however, it consumes a lot of water and generates CWW, with potential to pollute the bodies of water. Particular efforts are needed to develop technologies to reduce water consumption and to take advantage of the residues generated from the coffee fruits processing in order not to compromise the sustainability of the peeled cherry coffee production.

The reduction of water consumption has been occurring through the development of increasingly efficient machines for water use, which should be part of the new coffee processing units. The reduction of the water consume can be efficiently obtained by adjustments in the processing unit that allow the reuse of CWW in the hulling stage. In this case, the consume can be 0.5 L of water per liter of processed fruits, without compromising the beverage quality.

The CWW contains organic and inorganic matter formed by elements such as N, P, K, Ca and Mg, that might be used for plant nutrition; since the organic matter improves the physical-chemical and biological conditions of the soil. Several authors recommend that CWW be used for crops ferigation by reducing the expenses with the use of fertilizers. The CWW reuse in processing increases its nutrients concentration, facilitating the logistic of application in the crop.

11 REFERENCES

ABNT. Associação Brasileira de Normas Técnicas. *NBR 13969*. tanques sépticos - unidades de tratamento complementar e disposição final dos efluentes líquidos: projeto, construção e operação. Rio de Janeiro, 1997. Disponível em <http://www.acquasana.com.br/legislacao/nbr_13969.pdf>. Acesso em: 31 mar. 2015.

ANDRADE, F. V. *Ácidos orgânicos e sua relacão com adsorcão, fluxo difusivo e disponibilidade de fósforo em solos para plantas*. 2004. 42f. Tese (Doutorado em solos e nutricao de plantas). Universidade Federal de Vicosa, Vicosa, MG: 2004.

EUCLYDES, H. P. *Atlas digital das águas de Minas*: uma ferramenta para o planejamento e gestão dos recursos hídricos. Coordenacão técnica, direcão e roteirizacão. 2. ed. Belo Horizonte: RURALMINAS; Vicosa, MG: UFV, 2007. 1 (CD-ROM)

BORÉM, F. M. Anatomía e composicão química do fruto e da semente do cafeeiro. In: BORÉM, F. M. (Ed.). *Pós-colheita do café*. Lavras, MG: UFLA, p. 19-40. 2008a.

BRASIL. Presidencia da República. Leí n° 9433, de 8 de Janeiro de 1997. Institui a Política Nacional de Recursos Hídricos, cria o Sistema Nacional de Gerenciamento de Recursos Hídricos. *Diario Oficial da Uniao*, Brasilia 9 jan. 1997. Disponível em: <http:// www.planaito.Rov.br/ccivil 03/leis/l9433.htm>. Acesso em: 3 dez. 2014.

CAMPOS, C. M. M.; PRADO, M. A. C; PEREIRA, E. L. Caracterizado físico-química, bioquímica e energética da água residuária do café processado por via úmida. *Bioscience Journal*, Uberlandia, MG: v. 26, n. 4, p. 514-524, July/Aug. 2010.

CONAMA. Conselho Nacional do Meio Ambiente. Resolucão nº 430, de 13 de maio de 2011, publicado no DOU em 16 maio 2011. Dispõe sobre as condições e padrões de lançamento de efluentes. Publicado no DOU em *Diário Oficial da União*, Brasilia, 16 maio 2011. Disponível em: <http://www.mma.gov.br/port/conama/legiabre.cfm?codlegi=646>. Acesso em: 3 dez. 2014.

GARCIA, G. de O.; FERREIRA, P. A.; MATOS, A. T. de; RUIZ, H. A.; MARTINS FILHO, S. Alterações químicas de três solos decorrentes da aplicação de águas residuárias da lavagem e despolpa de frutos do cafeeiro conilon. *Engenharia na Agricultura*, Vicosa, MG: v.16, n.4, p. 416-427, out./dez., 2008.

IDAF. Instituto de Defesa Agropecuária e Florestal do Espírito Santo. *Instrução Normativa n° 11, de 23 de outubro de 2014a*, publicado no DOE em 29 out 2014. Disponível em: <http://www.legisweb.com.br/legislacao/?id=27630>. Acesso em: 3 dez. 2014.

IDAF. Instituto de Defesa Agropecuária e Florestal do Espírito Santo. *Instrução Normativa n° 15, de 23 de outubro de 2014b*, publicado no DOE em 29 out 2014. Disponível em: <http://www.legisweb.com.br/legislacao/?id=276274>. Acesso em: 3 dez. 2014.

IEMA. Instituto Estadual de Meio Ambiente e Recursos Hídricos. *Instrução Normativa n° 19, de 4 de outubro de 2005*, publicada no DOE em 6 out 2005. Disponível em: <http://www.meioambiente.es.gov.br/download/IN_IEMA_019_2005.pdf>. Acesso em: 3 dez. 2014.

LO MONACO, P. A. *Fertirrigação do cafeeiro com águas residuárias da lavagem e descascamento de seus frutos*. 2005. 101f. Tese (Doutorado em Engenharia Agrícola). Universidade Federal de Vicosa, Vicosa, 2005.

LO MONACO, P. A.; MATOS, A. T. de; MARTINEZ, H. E. P. FERREIRA, P. R.; RAMOS, M. M. Características químicas do solo após a fertirrrigação do cafeeiro com águas residuárias da lavagem e descascamento de seus frutos. *Irriga*, Botucatu: v.14, n.3, p. 348-364, jul./set., 2009.

MALTA, M. R.; CHAGAS, S. J. de R.; CHALFOUN, S. M. Colheita e pós-colheita do café: recomendacoes e coeficientes técnicos. *Informe Agropecuário*, Belo Horizonte: v.29, n.247, p. 83-94, nov./dez. 2008.

MATOS, A. T. de. Tratamento de resíduos na pós-colheita de café. In: BORÉM, F.M. (Ed.). *Pós-colheita do café*. Lavras, MG: UFLA, p. 159-201, 2008.

MATOS, A. T. de; LO MONACO, P.A. Tratamento e aproveitamento agrícola de resíduos sólidos e líquidos de lavagem e despolpa dos frutos do cafeeiro. *Revista Engenharia na Agricultura*. Viçosa, MG: UFV, 2003. 68p. (Boletim Técnico, 7).

MORELI, A. P. *Avaliação de um sistema de remoção de sólidos para maximização do uso da água no processamento dos frutos do cafeeiro*. 2010. 68f. Dissertação (Mestrado Produção Vegetal). Centro de Ciências Agrárias, Alegre, Universidade Federal do Espírito Santo. Alegre, ES. 2010.

MORELI, A. P. *Maximização da reutilização da água residuária do processamento dos frutos do cafeeiro: influências em características físico-químicas do efluente e qualidade da bebida do café*. 2013. 69f. Tese (Doutorado Produção Vegetal). Centro de Ciências Agrárias, Universidade Federal do Espirito Santo, Alegre, 2013.

PREZOTTI, L. C.; MORELI, A. P.; SOARES, S. F.; ROCHA, A. C. da. *Teores de nutrientes nas águas residuárias do café e características químicas do solo após sua aplicação*. Vitória, ES: Incaper, 2012. 24p. (Incaper, Documentos 208).

REIS, E. F. dos; MORELI, A. P.; SOARES, S. F.; PREZOTTI, L. C. A recirculação da água no processamento dos frutos do cafeeiro como importante ferramenta para a viabilidade ambiental. In: TOMAZ, M. A.; AMARAL, J. F. T.; OLIVEIRA, F. L.; COELHO, R. I. (Eds.). *Tópicos especiais em produção vegetal IV* [recurso eletrônico]. Alegre, ES: CAUFES, p. 530-546. 2013.

SILVA, I. R. e MENDONCA, E. S; Matéria orgânica do solo. In: NOVAIS, R. F. de; ALVAREZ V., V. H.; BARROS, N. F. de; FONTES, R. L. F.; CANTARUTTI, R. B.; NEVES, J. C. *Fertilidade do Solo*. Viçosa, MG: Sociedade Brasileira de Ciência do Solo, 2007. 1017p.

SILVA, J. de S. *Sistema de limpeza da água residuária do café*. Disponível em: https://www.youtube.com/watch?v=WQJOpsKFW7o. Acesso em: 5 jan. 2015.

SILVA, J. de S.; DONZELES, S. M. L.; SOARES, S. F.; MORELI, A. P.; VÍTOR, D. G. *Lavadores e sistema de reúso da água no preparo do café*. Brasilia, DF: Embrapa, 2014. 12p. (Circular Técnica, 04). Disponível em: <http://ainfo.cnptia. embrapa. br/digital/bitstream/¡tem/99089/l/Lavadores-e-s¡stema-de-reuso-da-agua.pdf>. Acesso em: 3 dez. 2014.

SOARES, S. F; DONZELES, S. M. L. Resíduos da pós-colheita do café: sólidos e líquidos. In: REIS, P. R.; CUNHA, R. L. da; CARVALHO, G. R. (Eds.). *Café Arábica*: da pós-colheita ao consumo. Lavras, MG: U. R.

EPAMIG SM, 2011b. p. 67-95.734p.

SOARES, S. F.; DONZELES, S. M. L; MORELLI, A. P; ROCHA, A. C. da. Crescimento de plantas de milho em vasos após a aplicação de água residuária do processamento do café. In: SIMPOSIO DE PESQUISA DOS CAFÉS DO BRASIL. 7., 11. *Anais*...Brasilia, DF: 2011a. (CD ROM).

SOARES, S. F.; SOARES, V. F.; SOARES, G. F.; ROCHA, A. C. da; MORELI, A. P.; PREZOTTI, L. C. Destinação da água residuária do processamento dos frutos do cafeeiro. In: FERRÃO, R. G.; FONSECA, A. F. A. da; BRAGANÇA, S. M.; FERRÃO, M. A. G.; De MUNER, L. H. (Eds.). *Café conilon*. Vitória, ES: Incaper, p.519-529. 2007.

SOARES, S. F.; DONZELES, S. M. L.; MORELI, A. P.; ROCHA, A. C. da; PREZOTTI, L. C.; SOARES, G. F.; SOARES, V. F. *Água residuária do café*: geração e aproveitamento. Belo Horizonte, MG: EPAMIG, 2008. (Circular Técnica, 30).

SOARES, S.F.; DONZELES, S. M. L; SOARES, G. F.; MORELI, A. P. Utilização da água residuária do processamento dos frutos do cafeeiro em alface. In: SIMPOSIO DE PESQUISA DOS CAFÉS DO BRASIL, 6., 2009. Vitória, ES. *Anais*... Brasília, DF: Embrapa Café, 2009. 1 CD-ROM

SOARES, S. F.; MORELI, A. P.; DONZELES, S. M. L.; PREZOTTI, L. C. Reúso da água na produção de café cereja descascado. Brasília, DF. EMBRAPA, 2012. 8p. (*Circular Técnica*, 01). Disponível em: <http://ainfo. cnptia .embrapa.br/digital/bitstream/item/86772/l/Reuso-da-agua.pdf>. Acesso em: 3 dez. 2014.

SOARES, S. F.; MORELI, A. P.; DONZELES, S. M. L.; PREZOTTI, L. C; ROCHA, A. C. da. Efeitos da água residuária do café em plantas e no substrato de cultivo de aveia, milho e alface. Brasília, DF. EMBRAPA, 2010. 8p. (C*omunicado Técnico*, 01). Disponível em: <http://ainfo.cnptia.embrapa.br/digital/bitstream/item/33456/l/Efeitos-das-aguas.pdfx>. Acesso em: 3 dez. 2014.

SOARES, S. F.; PREZOTTI, L. C.; DONZELES, S. M. L; MORELI, A. P. Estimativa da dose de água residuária do café para fertirrigação com base na saturação de K na CTC do solo... In: SIMPOSIO DE PESQUISA DOS CAFÉS DO BRASIL, 8., 2013, Salvador, BA. *Anais*...Brasília, DF: Embrapa Café, 2013. 1 CD-ROM

VILELA, P. S.; RUFINO, J. S. dos S. (Coord.). *Caracterização da cafeicultura de montanhas de Minas Gerais*. Belo Horizonte: INAES, 2010. 300 p (INAES. Cadeias Produtivas Café. Estudos 1).

Support

Consórcio Pesquisa Café

FAPES
FUNDAÇÃO DE AMPARO À PESQUISA E INOVAÇÃO DO ESPÍRITO SANTO

GOVERNO DO ESTADO DO ESPÍRITO SANTO
Secretaria de Ciência, Tecnologia, Inovação e Educação Profissional

Realization

Incaper
Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural

GOVERNO DO ESTADO DO ESPÍRITO SANTO
Secretaria da Agricultura, Abastecimento, Aquicultura e Pesca

Rua Afonso Sarlo, 160 - Bento Ferreira - Caixa Postal: 391
CEP: 29052-010 - Vitória, ES - Brasil
Telephone: 55 27 3636 9846 - biblioteca@incaper.es.gov.br
www.incaper.es.gov.br

ISBN 978-85-89274-32-6
9 788589 274326