Volume 7, Number 3 (June 2014) p. 349-366 • ISSN 1983-4195

IBRACON

REVISTA IBRACON DE ESTRUTURAS E MATERIAIS

IBRACON STRUCTURES AND MATERIALS JOURNAL

Quality of concrete plant wastewater for reuse

Qualidade da água residuária de usina de concreto para fins de aproveitamento

H. M. PAULA [a]
heberdepaula@ufg.br

M. S. O. ILHA [b]
milha@fec.unicamp.br

Abstract

Efficient water use is one of the most important requirements of cleaner production, and the use of the wastewater from concrete production can be an important means to this end. However, there are no Brazilian studies on the quality of concrete plant wastewater and the activities in which such water can be used. This paper aims to evaluate the quality of concrete plant wastewater and to propose guidelines for its treatment for non-potable applications. Wastewater samples were collected from three points in the studied treatment system, and tests were later performed in the laboratory to evaluate the water quality. The results obtained were compared with the limit values for the quality parameters that have been used for the analysis of the non-potable water supply in Brazil. The results indicate a need to at least add coagulation and pH correction processes to the treatment system.

Keywords: wastewater, concrete plants, water quality, treatment.

Resumo

O uso eficiente da água se constitui em um dos principais quesitos a serem contemplados dentro do conceito de produção mais limpa e o uso da água residuária da produção do concreto pode ser uma importante medida para este fim. Contudo, não se dispõe no Brasil de um estudo que indique a qualidade desta água e em quais atividades poderia ser reutilizada. O objetivo deste trabalho é avaliar a qualidade da água residuária de uma usina de concreto e propor diretrizes para o seu tratamento tendo em vista o reúso para fins não potáveis. Para tanto, foram coletadas amostras da água residuária em três pontos do sistema de tratamento existente na usina em estudo, sendo depois realizados ensaios em laboratório para a avaliação da sua qualidade. Os resultados obtidos forma comparados com os valores limite dos parâmetros de qualidade existentes nos principais documentos que vêm sendo empregados para a análise da água não potável para fins de abastecimento no pais. Os resultados obtidos indicam a necessidade de acrescentar ao sistema de tratamento existente, pelo menos, os processos de coagulação e a correção do pH.

Palavras-chave: água residuária, usinas de concreto, qualidade da água, tratamento.

---

[a] *Federal University of Goiás (Universidade Federal de Goiás), Department of Civil Engineering, Catalão/GO, Brazil;*

[b] *State University of Campinas (Universidade Estadual de Campinas - UNICAMP), School of Civil Engineering, Architecture and Urbanism of UNICAMP, Department of Architectural Construction, Campinas/SP, Brazil.*

Received: 04 Jun 2013 • Accepted: 24 Mar 2014 • Available Online: 02 Jun 2014

1. Introduction

Water usage is significant in concrete plants, not only in concrete production but also for washing waste in concrete mixer trucks, washing patios, and sprinkling on aggregates to reduce dust (Sealey, Phillipse, and Hill [1]; Cement Concrete & Aggregates Australia [2]). The use of wastewater can reduce the consumption of potable water and contribute to the cleaner production of concrete with regard to water usage.

Su, Miao, and Liu [3] emphasized that concrete wastewater shows high pH values, between 11 and 12, and high alkalinity due to the presence of hydroxides and carbonates in addition to the elevated concentration of solids. These characteristics make it necessary to treat wastewater prior to final disposal, whether in water or soil.

Concrete plants are subject to environmental licensing according to CONAMA Resolution No. 237 [4] because the production process involves the generation of environmental impacts. Lima et al. [5] surveyed the primary polluting activities of a concrete plant with a capacity of 40 $m^3.h^{-1}$, which include transporting raw materials and concrete by trucks; the molding of specimens; washing the concrete mixer trucks; filling the trucks; and vehicle maintenance. Additionally, the authors performed a Risk Prevention Analysis, which classifies impacts by severity and frequency, and concluded that washing the trucks has the largest impact on the environment among the activities that take place within the plant, with an importance of 10 on a scale with a maximum value of 20. The wastewater from washing has a modified pH that can cause the death of fish and contaminate groundwater.

The Brazilian national policy on solid wastes, instituted by Law No. 12305 [6], states that whenever liquids have properties that make it impossible to dispose of them in the public sewer system or in bodies of water or that require technically or economically unviable solutions with the best technology available, clean technologies must be adopted, developed, and improved to minimize environmental impacts.

CONAMA Resolution No. 448 [7] establishes in its first paragraph that civil construction wastes cannot be disposed of in solid urban waste landfills, in waste areas, on hillsides, in bodies of water, in empty lots, or in other areas protected by law. Thus, civil construction firms must meet the requirements of CONAMA Resolution No. 430 [8], which establishes the conditions and standards for wastewater disposal in receiving bodies. The 2nd Article of this resolution establishes that wastewater disposal in soil, even after treatment, is not subject to the parameters and standards for disposal in the resolution; however, such wastewater must not cause the pollution or contamination of surface and subterranean waters. For the reuse of concrete wastewater, the type of treatment depends on the activity for which the treated water will be used, normally the non-potable water supply.

NBR 15900 [9] establishes the parameters for concrete mixing water, taking into consideration the use of the concrete and which wastewater can be reused, such as water from washing the concrete mixer trucks. According to this standard, seawater, brackish water, or water from sewage or treated sewage cannot be used for mixing concrete.

Water from alternative sources must meet a series of chemical and physical requirements to be used in concrete production, not only so that the concrete's properties are maintained, such as setting time and expected strength, but also so that the water used does not harm the concrete's durability.

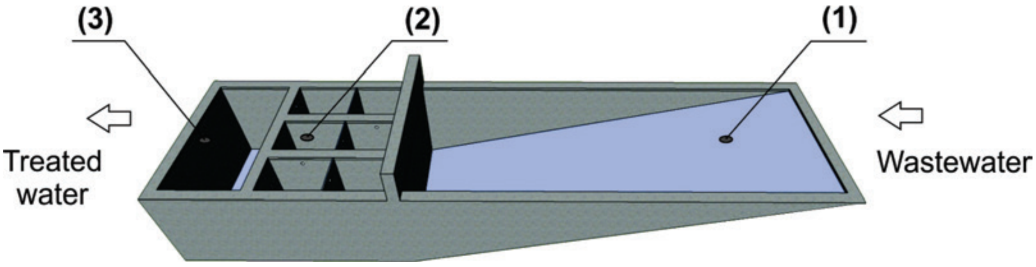
The studies found in the literature review indicate that concrete produced with wastewater from the factory shows compressive strength greater than 90% of that obtained for concrete produced with potable water, which is acceptable according to ASTM C94/C94M [10] (Sandrolini and Franzoni [11]; Su, Miao, and Liu [3]; Chatveera, Lertwattanaruk, and Makul [12]) and EN 12390-2 [13] (Tsimas and Zervaki [14]), in addition to initial setting times with differences of less than 30 minutes, which is acceptable according to ASTM C403/C403M [15] (Su, Miao, and Liu [3]) and EN 196-3 [16] (Tsimas and Zervaki [14]).

Concrete mixing water must not contain impurities that impact the cement hydration reactions and the formation of its compounds.

The use of wastewater in other activities that do not require potable water, such as washing concrete mixer trucks, was evaluated in only one study in the investigated literature; the study found that the concentration of solids must be monitored (Sealey, Phillips, and Hill [1]).

All of the evaluated studies, regardless of the destination of the wastewater, included a treatment system for improving the water quality parameters (Sealey, Phillips, and Hill [1]; Tsimas and Zervaki [14]), which required, for its definition, the characterization of the

Figure 1 – Wastewater treatment system and sample collection points for water quality characterization: (1) wastewater inlet chamber from washing of trucks and the patio; (2) intermediate decanting chamber; (3) outlet chamber



wastewater and the purpose for which the water would be treated. The objective of this article is to evaluate concrete plant wastewater quality and propose guidelines for its treatment for use in activities that do not require potable water in the concrete plant itself, such as washing the concrete mixer trucks, sanitizing the plant environment, flushing toilets, irrigating green areas, and washing patios. The article evaluates a single case study that may serve as a basis for the development of similar studies elsewhere.

2. Methodology

The study analyzed a concrete plant located in the southeastern region of the state of Goiás, Brazil, with an average monthly production of 2000 m³ of concrete.

An initial survey of several concrete plants indicated that the system typically used for wastewater treatment is composed of two or three sedimentation tanks. In the plant investigated in this study, the treatment system is composed of a wastewater inlet tank, six sedimentation chambers, and a wastewater outlet tank.

The water samples for the quality tests were collected at three distinct points in the treatment system (Figure 1): (1) the inlet chamber, whose opening is found at floor level, (2) one of the sedimentation chambers, and (3) the outlet chamber.

The water inlet for the treatment system is found at floor level; thus, surface runoff, which contains debris from the patio, is also directed to this location. Therefore, collections were performed during two periods: one in the dry season and one in the rainy season. The samples for the determination of the apparent color, turbidity, and concentration of iron were collected at eight different times (C1 to C8), with three (C1 to C3) in the dry period (October and November 2012) and five (C4 to C8) in the rainy period (December 2012 and January and February 2013).

In all cases, the samples were collected on the liquid surface using plastic bottles (PET). After collection, the samples were labeled and immediately transported to the laboratory for testing according to the APHA methods [17] shown in Table 1.

The tests evaluated the following characteristics of water quality: apparent color, turbidity, residual chlorine, thermo-tolerant coliforms, chloride, dissolved oxygen, alkalinity, hardness, and concentrations of ammonia, iron, and chlorides.

Due to the availability of the reagents needed for the tests, the evaluation of residual chlorine and the test for the concentration of ammonia were only performed in the dry period (collections C1 to C3), and the tests for the concentrations of chloride and dissolved oxygen (DO) were conducted only in the rainy period (C4 to C8). Finally, the tests for hardness, alkalinity, pH, and thermo-tolerant coliforms were performed only on some of the collections and points in the treatment system.

The oxygen concentration readings were performed at three distinct times: five, ten, and fifteen minutes.

Table 1 – Parameters selected for the evaluation of water quality, limit values for non-potable water for recovery/reuse, and testing methods

Parameters	I	II	III	IV	Method
pH	6 to 9	6 to 9	6 to 9	6 to 8	SM 4500-H+ B
Apparent color	≤ 10 $mg.L^{-1}$	< 30 $mg.L^{-1}$	–	< 15 $mg.L^{-1}$	SM 2120 C
Turbidity	≤ 2 NTU	< 5 NTU	≤ 2 NTU	< 2 NTU and, for less restrictive uses, < 5 NTU	SM 2130 B
Residual chlorine	–	Max. 1 $mg.L^{-1}$ (a)	> 1.0 $mg.L^{-1}$	0.5 to 3.0 $mg.L^{-1}$	SM 4500 G
Thermo-tolerant coliforms	–	–	–	Absence in 100 mL	SM 9221C
Chloride	–	<350 $mg.L^{-1}$ (a) < 100 $mg.L^{-1}$ (b)	–	–	SM 4500 B
Alkalinity	–	–	50 to 150 $mg.L^{-1}$ $CaCO_3$ (c)	–	SM 2320 B

Note: SM - Standard Methods, Source: APHA (17)

I - SAUTCHUK et al. (19), water quality standard recommended for Class 1 reuse waters (washing of vehicles and flushing of toilets).

II – SAUTCHUCK et al. (19), water quality standard recommended for Class 3 reuse waters (irrigation of green areas and gardens).

III – EPA/600/R-12/618 (20) water quality standard indicated for urban reuse (for all types of irrigation, washing of vehicles, flushing of toilets, firefighting systems, commercial air conditioning systems, and uses, accesses, and exposures similar to these).

(c) Values for reused water.

IV – NBR 15527 (18).

(a) For surface irrigation; (b) For irrigation with sprinklers.

Because NBR 15527 [18] is the only standard in Brazil that considers non-potable water quality, this standard was considered as a reference for the analysis of the quality parameters. This approach is valid because the parameters refer to treated water; that is, they refer to the non-potable water supply, regardless of its origin. Additionally, two other documents were considered that have also been used as a reference for the evaluation of the quality of the non-potable water supply in Brazil: Sautchuk et al. [19] and EPA/600/R-12/618 [20].

Thus, the results for pH, apparent color, turbidity, residual chlorine, thermo-tolerant coliforms, chlorides, and alkalinity were compared with the limit values for non-potable water found in Sautchuk et al. [19], EPA/600/R-12/618 [20], NBR 15527 [18], Manca and Jannuzzi [21], and Lopes [22].

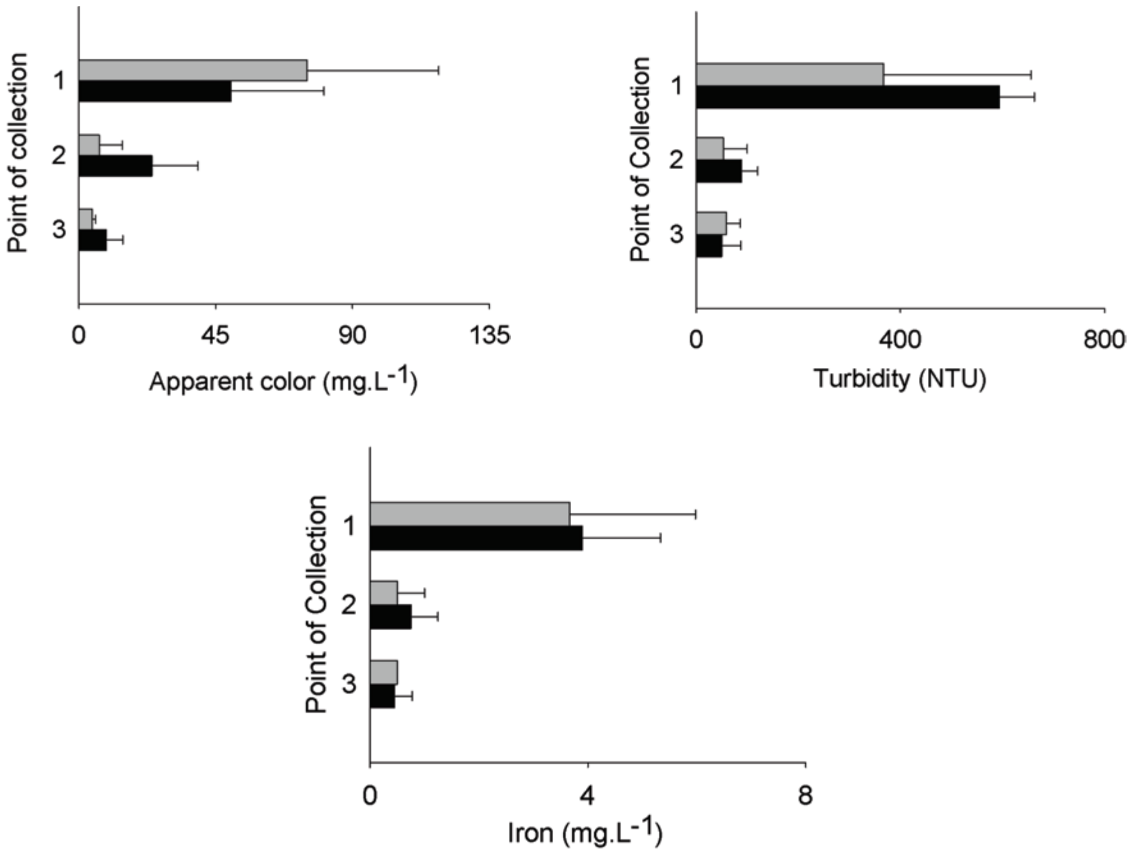
In turn, the results for the concentration of iron (Thiocyanate Method, according to Boltz and Howell [23]) were compared with the limit values found in CONAMA Resolution No. 430 [8] for the classification of water sources, using Class III waters as a reference (maximum iron concentration of 5.0 $mg.L^{-1}$). The iron ion in the water may be responsible for the appearance of stains on clothes, sanitary devices, and other surfaces (Moruzzi [24]).

To evaluate the water hardness, as determined according to the SM 2340 C Method (APHA [17]), water hardness is characterized by the presence of alkaline earth salts, such as calcium and magnesium. These elements confer a disagreeable flavor and a laxative effect, reduce the formation of soap suds, thereby increasing soap consumption and causing scaling on pipes and boilers (Roloff [25]). The values found in Von Sperling [26] were considered as a reference to evaluate the hardness of the water. According to these standards, soft water has less than 50 $mg.L^{-1}$ $CaCO_3$, moderately hard water has between 50 and 150 $mg.L^{-1}$ $CaCO_3$, hard water has between 150 and 300 $mg.L^{-1}$ $CaCO_3$, and very hard water has more than 300 $mg.L^{-1}$ $CaCO_3$.

For dissolved oxygen (DO), which was determined according to the SM 4500-O Method (APHA [17]), the value recommended by Fiorucci and Benedetti Filho [27] (2.5 $mg.L^{-1}$) was used to avoid problems of corrosion in pipes and accessories.

Finally, a comparative analysis was performed for the results obtai-

Figure 2 – Average values for apparent color, turbidity, and iron concentration for samples collected at three points in the treatment system: 1 (inlet chamber), 2 (intermediate chamber), and 3 (outlet chamber). The gray bars represent the values obtained for samples collected in the rainy period, and the black bars represent the values obtained for samples collected in the dry period. Error bars indicate the standard deviation



ned for the apparent color, turbidity, and iron concentration using the non-parametric Wilcoxon test for paired results, with a significance level of 0.05. This test was selected due to the small amount of data, the dependence of the results obtained on the three points of the treatment system, and the lack of evidence of normality of the data (Bunchaft and Kellner [28]; Volpato and Barreto [29]). For this analysis, the data from the two collection periods (dry and rainy) were considered together.

3. Results and discussion

Figure 2 shows the results for apparent color, turbidity, and iron concentration for the samples collected at the three points of the treatment system in the rainy and dry periods.

The apparent color of the samples collected in the rainy period was higher at point 1, indicating the determinant contribution of the surface runoff from the concrete plant patio in this parameter.

As the water passed through the treatment system, there was a significant reduction in the apparent color for both the rainy and dry periods. The average value of the apparent color in the rainy period was 75 mg.L^{-1} at point 1, 6.7 mg.L^{-1} at point 2, and 4.3 mg.L^{-1} at point 3. In the dry period, these values were 50 mg.L^{-1} for point 1, 24 mg.L^{-1} for point 2, and 9.0 mg.L^{-1} for point 3. The application of the statistical test to the complete data set (rainy and dry periods together) confirmed the effectiveness of the system used to reduce this parameter because the values obtained for the samples from point 1 were significantly different from those obtained for points 2 and 3 ($p < 0.05$); in addition, the values obtained for point 2 were significantly different from those obtained for point 3.

The turbidity and concentration of iron showed a similar behavior to the apparent color, with significantly higher values at point 1 and a significant decrease as the water passed through the treatment system.

The water collected at point 1 showed large quantities of suspended solids, with turbidity values between 200 NTU and 700 NTU. Although the average values were higher in the dry period, the values in the rainy period were similar at this point, indicating that the determining factor for turbidity was the difference in the quantities of debris in the wash water from each concrete mixer truck.

The results for turbidity at point 1 were significantly higher than those obtained for point 2 and point 3 ($p = 0.0017$ in both cases). In contrast, the results obtained for point 3 were not significantly different from those found for point 2, indicating that there was little improvement in this parameter between these two points.

The concentration of iron at each of the analyzed points was slightly higher in the dry period due to the lower volume of surface runoff water in the treatment system during the dry period. The presence of this metal was primarily due to concrete ballast that returns to the plant, which sediments as it passes through the treatment system.

Similar to turbidity, the results obtained for point 1 were significantly higher than those obtained for point 2 and point 3 ($p = 0.017$ in both cases). The results obtained for point 3, however, were not significantly different from those obtained for point 2 ($p = 0.208$), indicating that there was little improvement in this parameter between these points.

The similarity between the results obtained for points 2 and 3 for turbidity and the concentration of iron were due to the relatively high velocity of water flow in the treatment system, which made particle sedimentation difficult.

To analyze the viability of reusing treated water for non-potable purposes, the values of the parameters investigated at point 3 were considered, from the outlet chamber of the treatment system. For apparent color, the limits specified in the reference document for non-potable water quality were met, with the exception of two collections performed on subsequent days in the rainy period, in which the results were only higher than the limit recommended by Sautchuk et al. [19] for class I reuse waters, which are for washing vehicles and flushing toilets. Thus, if these were the final uses of the treated water, an additional treatment process would be necessary to remove the color.

Figure 3 – Chloride concentration of samples collected in the rainy period (collections C5 to C8). The white bars show the values obtained for the samples at point 1, the light gray bars show the values obtained for the samples at point 2, and the bars with the striped pattern show the values obtained for the samples at point 3

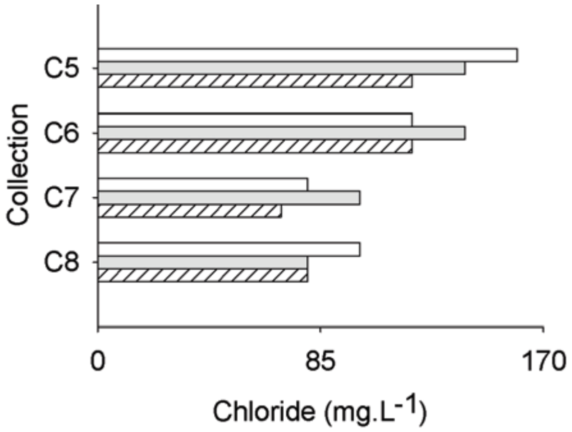
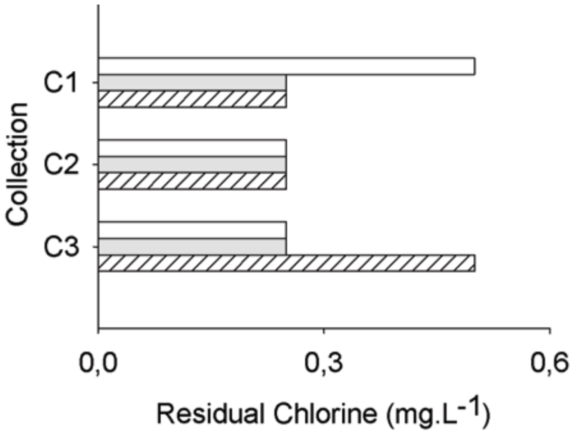


Figure 4 – Residual chlorine concentration of samples collected in the dry period (collections C1 to C3). The white bars show the values obtained for the samples collected at point 1 (inlet chamber), the light gray bars show the values for the samples collected at point 2 (intermediate chamber), and the bars with the striped pattern show the values for the samples collected at point 3 (outlet chamber)



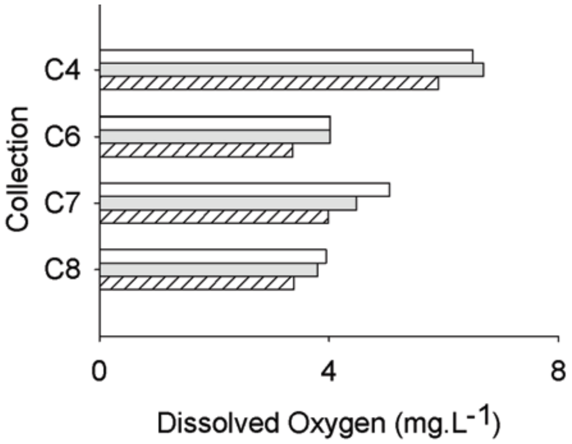
For turbidity, the values found at point 3 were always higher than the limits recommended for non-potable water in the reference documents used, which also indicates a need for treatment in addition to that existing at the plant.

As previously noted, limit values for the concentration of iron in non-potable water were not found in the consulted reference documents. Therefore, the limit value for potable water found in CONAMA 430 [8] was considered; all of the values obtained were within the limits established by the referenced resolution.

Figure 3 shows the results for the concentration of chloride in samples from four collections performed in the rainy period from the three points studied. In the dry period, this test was performed on only the samples from some of the collections due to the availability of the reagents, resulting in an average of 40 mg.L^{-1} at the three collection points. There was a small amount of variability between the data in this period; however, it was not significant. In the rainy period, the values were higher (average value of 120 mg.L^{-1} for the three collection points).

The behavior of this parameter was not the same in all of the collections; in some of the collections, the highest values occurred in the intermediate chamber (point 2), and in others, the highest values occurred in the inlet (point 1). According to Su, Miao, and Liu [3], the quantity of chloride increases with tank depth due to the sedimentation of solids. Because sample collection was performed

Figure 5 – Dissolved oxygen concentration of the samples collected in the rainy period (collections C4, C6, C7, and C8) at three points in the treatment system: 1 (white bars), 2 (light gray bars), and 3 (striped bars)



near the surface of the water, sedimentation of suspended material occurred from one point to another, decreasing the quantity of chloride dissolved in the water.

Only Sautchuk et al. [19] presented a limiting value for this parameter for the non-potable water supply, and all of the values found in the collected samples were less than this value. Therefore, an additional treatment process would not be necessary to reuse the treated water.

The residual chlorine concentration from one sample collected in the rainy period was 0.25 mg.L^{-1} for points 1 and 2, and 0.50 mg.L^{-1} for point 3. The values for this parameter for the dry period (collections C1 to C3) are shown in Figure 4. The residual chlorine concentration was not homogeneous in the different samples collected; this parameter was significantly higher at point 1 in one sample and at point 3 in another. With the exception of the last collection, the values obtained for points 2 and 3 were equal. The results obtained were lower than the values found in NBR 15527 [18], which suggest an interval from 0.5 to 3.0 mg.L^{-1}.

The dissolved oxygen (DO) concentrations for the samples collected in the rainy period are shown in Figure 5. There was a slight decrease in this parameter from point 1 to point 3 in the majority of the collections. The limit proposed by Fiorucci and Benedetti Filho [27], however, was exceeded in all of the samples, regardless of the point of collection.

Thus, to reuse the water, it would be necessary to correct the dissolved oxygen concentration because elevated values of this parameter can cause corrosion of pipes and accessories, among other problems. The average temperature of the concrete wastewater was maintained between 24.7 and 27.8°C. A higher temperature would cause a decrease in the solubility of oxygen in the water.

The alkalinity values of the wastewater were elevated due to the presence of concrete ballast residues in the concrete mixer trucks. The alkalinity values were obtained from all three points: one in each collection performed in the month of October 2012 (C1 – point 1 and point 3; C2 – point 2) and one for the last collection in the month of February 2013 (C8), presented values respectively, of 1200 and 760 mg.L^{-1} (point 1), 1680 and 660 mg.L^{-1} (point 2), and 1550 and 680 mg.L^{-1} (point 3), respectively, exceed the limits for water reuse indicated by the EPA/600/R-12/618 [20]. The pH was determined for the samples collected at the three investigated points in the dry period and in the first collection (C4) from the rainy period; the results showed an average value of 12.5. Cement is rich in carbonates and bicarbonates, and these were the primary causes of the elevated alkalinity values and the elevated pH. Thus, the pH must be decreased to reuse the treated water.

The tests for total hardness (determined for samples from collections C1 and C2 from the dry period and for points 1 and 3 only) resulted in values greater than 1400 mg.L^{-1} $CaCO_3$, indicating that the water was very hard (>300 mg.L^{-1} $CaCO_3$). This result was higher than the result for alkalinity, which showed a lower concentration of soluble bicarbonates. Waters with elevated hardness and alkalinity cause a continuous and harmful internal inorganic scaling formation process in pipes, initially from the supersaturation of slightly soluble or insoluble salts, resulting from the evaporation of water. Thus, an additional treatment process is needed to reuse the wastewater.

Thermo-tolerant coliforms were not found in any of the samples collected from the three investigated points, which indicates that there was no type of microbiological contamination in the water collected from the treatment system.

Table 2 shows a summary of the results obtained, with indications of the water quality parameters and the type of treatment to be conferred on the non-potable water for reuse in the different activities identified in the plant that do not require potable water. Although no coliforms were detected in the wastewater, disinfection is recommended as a preventative measure because there is a possibility of skin contact with the treated water. Additionally, the hardness and dissolved oxygen in the water need to be corrected. These

Table 2 – Summary of the results obtained for concrete plant wastewater quality and identification of additional treatment requirements for non-potable reuse

Predicted non-potable use	Parameters from the reference documents		Additional treatment required
	Required	Exceeded in this study	
Washing of concrete mixer trucks	pH Apparent color Turbidity Alkalinity	All	Acidification – pH correction. Chemical coagulation – apparent color and turbidity. Disinfection (possibility of contact).
Flushing of toilets	pH Apparent color Turbidity Residual chlorine Chloride	pH apparent colorturbidity	
Washing of patios*	pH Apparent color Turbidity Residual chlorine Thermo-tolerant coliforms	pH apparent colorturbidity	

* Considering the limit values for use in irrigation.

parameters were not considered in the consulted documents but are important for the wastewater in question.

4. Conclusions

The concrete wastewater quality indicates a need for additional treatment for non-potable reuse in the plant. Considering the reference documents that have been used in Brazil for non-potable water quality reuse, the pH, apparent color, and turbidity need to be corrected. For the probable final non-potable uses, there is also a need to correct the alkalinity and the hardness.

Thus, for non-potable use in the plant, coagulation and pH correction would at least need to be added to the treatment process. The use of chemical coagulants, such as aluminum sulfate and ferric chloride, however, increases the volume of sludge generated during treatment, in addition to altering some physical and chemical parameters of the water. There are also problems associated with aluminum waste that can cause Alzheimer's at concentrations greater than 200 $\mu g.L^{-1}$ (Bhatti, Mahmood, and Raja [30]). For this reason, it is important to investigate the possibility of using natural coagulants with a lower environmental impact.

Additionally, preventative disinfection is recommended due to the possibility of users' direct contact with the treated water.

The water's passage through the existing treatment system in the plant, which is essentially composed of sedimentation chambers, provided an improvement in the wastewater quality, with the exception of turbidity and the concentration of iron, in which there was no significant difference between the samples collected at point 2 (the intermediate chamber) and those collected at point 3 (the outlet chamber). This result may be caused by the relatively high water flow velocity, which makes particle sedimentation difficult.

5. References

[01] SEALEY, B.J; PHILLIPS, P.S; HILL, G.J. Waste management issues for the UK ready-mixed concrete industry. Resources, Conservation and Recycling, v. 32, p. 321-331, 2001.

[02] CEMENT CONCRETE & AGGREGATES AUSTRALIA. Use of Recycled Water in Concrete Production. Australia, 2007; 27p.

[03] SU; MIAO, B; LIU, F. Effect of wash water and underground water on properties of concrete. Cement and Concrete Research, v. 32, p. 777-782, 2002.

[04] BRASIL. Ministério do Meio Ambiente. Resolução CONAMA Nº 237, DE 22 DE DEZEMBRO DE 1997. Regulamenta os aspectos de licenciamento ambiental estabelecidos na Política Nacional do Meio Ambiente [Ministry of the Environment. CONAMA Resolution No. 237, DECEMBER 22, 1997. Regulates the aspects of environmental licensing established in the National Environmental Policy]. Published in the DOU No. 247, Monday, 22 December 1997. Diário Oficial da União, Brasília, 22 December 1997.

[05] LIMA, A. P.; MOREIRA, B.; ARAÚJO, L. E.; GABRIELE, P. D.; CARVALHO, M. Sustentabilidade na Construção Civil [Sustainability in Civil Construction]. In: Congresso Nacional de Excelência em Gestão, 5°, 2009, Niterói. Anais, Niterói, 2009, 16p.

[06] BRASIL. Ministério do Meio Ambiente. Lei Nº 12.305: Institui a Política Nacional de Resíduos Sólidos; altera a Lei no 9.605, de 12 de fevereiro de 1998; e dá outras providências [Ministry of the Environment. Law No. 12,305: Institutes the National Policy for Solid Wastes, alters Law No. 9,605, February 12, 1998, and provides other measures]. Brasília, 2010.

[07] BRASIL. Ministério do Meio Ambiente. Resolução CONAMA Nº 448, DE 18 DE JANEIRO DE 2012 Publicada no DOU Nº 14, quinta-feira, 19 de janeiro de 2012. Altera os arts. 2º, 4º, 5º, 6º, 8º, 9º, 10º e 11º da Resolução nº 307, de 5 de julho de 2002, do Conselho Nacional do Meio Ambiente [Ministry of the Environment. CONAMA Resolution No. 448, JANUARY 18, 2012 Published in the DOU No. 14, Thursday, January 19, 2012. Alters Art. 2, 4, 5, 6, 8, 9, 10, and 11 of Resolution No. 307, July 5, 2002, from the National Council on the Environment]. Diário Oficial da União, Brasília, 19 January 2012.

[08] BRASIL. Ministério do Meio Ambiente. Resolução CONAMA Nº 430, DE 13 DE MAIO DE 2011, Dispõe sobre as condições e padrões de lançamento de efluentes, Complementa e altera a Resolução no 357, de 17 de março de 2005, do Conselho Nacional do Meio Ambiente-CONAMA [Ministry of the Environment. CONAMA Resolution No. 430, MAY 13, 2011, Adopts provisions and standards for the disposal of wastewater, complements and alters Resolution No. 357, March 17, 2005, of the National Council for the Environment]. Diário Oficial da União, Brasília, 16 de Maio. 2011.

[09] ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. Água para amassamento do concreto Parte 1: Requisitos – NBR 15900 [Water for mixing concrete Part 1: Requirements – NBR 15900], Rio de Janeiro, 2009.

[10] AMERICAN SOCIETY FOR TESTING AND MATERIALS. ASTM C94 / C94 M – 99: Standard Specification for Ready-Mixed Concrete. Philadelphia: American Society for Testing and Materials, 1999.

[11] SANDROLINI, F; FRANZONI, E. Waste wash water recycling in ready-mixed concrete plants. Cement and Concrete Research, v. 31, p. 485-489, 2001.

[12] CHATVEERA, B; LERTWATTANARUK, P e MAKUL, N. Effect of Sludge Water from Ready-mixed Concrete Plant on Properties and Durability of Concrete Cement and Concrete Composites. Elsevier, v. 28, n. 5, p. 441-450, 2006.

[13] EUROPEAN COMMITTEE FOR STANDARDIZATION (CEN). EN 12390-2: Testing hardened concrete – Part 2: Making and curing specimens for strength tests. Brussels. 2008.

[14] TSIMAS, S; ZERVAKI, M. Reuse of waste water from ready-mixed concrete plants. Management of Environmental Quality: An International Journal, v. 22, n. 1, p. 7–17, 2011.

[15] AMERICAN SOCIETY FOR TESTING AND MATERIALS. ASTM C403/C403 M-99: Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance. Philadelphia: American Society for Testing and Materials, 1999.

[16] EUROPEAN COMMITTEE FOR STANDARDIZATION (CEN). EN 196-3: Methods of testing cement – Part 3: Determination of setting times and soundness. Brussels, 2008.

[17] AMERICAN PUBLIC HEALTH ASSOCIATION. Standard methods for the examination of water and wastewater. 22 ed., 2012. 1496p.

[18] ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS [Brazilian Association of Technical Standards]. Água de chu-

va - Aproveitamento de coberturas em áreas urbanas para fins não potáveis – Requisitos. - NBR 15527 [Rain water – Recovery from roofs in urban areas for non-potable uses – Requirements – NBR 15527], Rio de janeiro, 2007.

[19] SAUTCHUK, C.; FARINA, H.; HESPANHOL, I.; OLIVEIRA, L. H.; COSTI, L. O.; ILHA, M.S.O.; GONÇALVES, O.M.; MAY, S.; BONI, S.S.N.; SCHMIDT, W. (2005) – Conservação e reúso da água em edificações – Manual da FIESP [Conservation and reuse of water in buildings – Manual of the FIESP]. São Paulo. 151 p.

[20] U.S. ENVIRONMENTAL PROTECTION AGENCY (USEPA). 2012. Guidelines for Water Reuse. EPA. EPA/600/R-12/618, September 2012. Environmental Protection Agency. Washington, D.C.

[21] MANCA, R. S.; JANNUZZI, G. M. O planejamento integrado de recursos do setor energético como base para o gerenciamento dos recursos hídricos em áreas urbanas [The integrated planning of resources from the energy sector as a basis for the management of water resources in urban areas]. Engenharia Ambiental – Espírito Santo do Pinhal, v. 5, n. 3, 2008, p. 323 – 341.

[22] LOPES, G. B. Estudo de viabilidade técnica do aproveitamento de água de chuva para fins não potáveis na Universidade Federal de Uberlândia [Study of the technical viability of rain water recovery for non-potable uses in the Federal University of Uberlândia], Uberlândia (MG), Uberlândia, 2012, Masters Dissertation– Federal University of Uberlândia, 190 p.

[23] BOLTZ; HOWELL. Colorimetric Determination of Nonmetals. 2nd ed., vol. 8. John Wiley & Sons Inc, 1978. 564 p.

[24] MORUZZI, R. B. Oxidação e Remoção de Ferro e Manganês em Águas para fins de Abastecimento Público ou Industrial – uma abordagem geral [Oxidation and Removal of Iron and Manganese in Waters for Public or Industrial Supply Purposes]. Revista de Engenharia e Tecnologia, V. 4, n. 1, p. 29-43, 2012.

[25] ROLOFF, T. A. Efeitos da não Aplicação do Controle de Qualidade da Água nas Indústrias Alimentícias [Effects of Not Applying Water Quality Control in the Food Industry]. SaBios: Rev. Saúde e Biol., v. 1, n.1 p.52-57, 2006.

[26] VON SPERLING, M. Introdução à qualidade das águas e ao tratamento de esgoto [Introduction to water quality and sewage treatment]. 3nd ed. – Belo Horizonte: Department of Sanitary and Environmental Engineering; Federal University of Minas Gerais; 2006.

[27] FIORUCCI, A. R; BENEDETTI FILHO, E. A importância do oxigênio dissolvido em ecossistemas aquáticos [The importance of dissolved oxygen in aquatic ecosystems]. Química Nova na Escola, n. 22, p. 10 – 16, 2005.

[28] BUNCHAFT, G.; KELLNER, L. H. M. H. Estatística sem mistérios [Statistics without mysteries]. 2nd. Ed. Vozes. Petrópolis. 2001.

[29] VOLPATO, G; BARRETO, R. Estatística sem dor [Painless Statistics]. Botucatu: Best Writing, 2011. 64p.

[30] BHATTI, Z. A.; MAHMOOD, Q.; RAJA, I. A. Sewage Water Pollutants’ Removal Efficiency Correlates to the Concentration Gradient of Amendments. J. Chem. Soc. Pak., V. 41, n. 4, p. 665 – 671, 2009.