Quantification of Solids Production in Potable Water Treatment Plants in Minas Gerais, Brazil: Study of Two Cases

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Abstract—This work comments some of the more recent and important studies regarding the treatment of liquid effluents produced by potable water treatment plants in Brazil and presents the formula used by the authors to estimate the solids production in units for this purpose in Minas Gerais. It is easy to apply in practical situations and the results obtained by its use are not far from the values found in two real cases. In this way, the authors believe that the formula can be useful in preliminary projects of this nature.

Keywords—Cases studies of solids and sludge production, potable water treatment plants, solids production in potable water treatment plants, solids production in potable water treatment plants. treatment of discharges from potable water treatment plants.

I. INTRODUCTION

Brazilian legislation, which rules the disposal of liquid effluents of potable water treatment plants (PWTP) in rivers and lakes, imposes the adequate treatment of those effluents. The units in which the treatment is performed are known as liquid wastes treatment plants (LWTP). In those units, the liquid waste passes through settling tanks and the sludge from them is concentrated and dehydrated. The best solution for the final disposal of the dehydrated sludge is still under discussion.

The efforts to introduce the use of LWTP in Brazilian PWTP are recent. Although studies on this matter date form 1990 [3], only from 2000 to these days they started to appear more frequently in technical events. Among Brazilian authors, Achon [1] presents special importance. She has investigated and described the characteristics of liquid wastes produced by many Brazilian PWTP.

Moreira Filho [7] extensively described the basic characteristics of LWTP that could be used in Minas Gerais. Particularly in this Brazilian state, the first great LWTP was implanted in Rio Manso system, which produces 3.7 m³/s of potable water. Demattos [4] and Soares [10] studied it, but since then new studies were few. It is important to notice that since 2006 isolated studies on his matter can be found [11].

More recently, also as isolated efforts, Ribeiro [9] and Oliveira [8] studied and presented some results of the liquid wastes characteristics of PWTP in the cities of Uberlândia and Itaguara, respectively. Nevertheless, no mathematical relation between them, the quantities of chemical products dosed during the treatment and the solids production was obtained.

Studies were conducted by FUMEC University, Minas Gerais, in association with a consulting enterprise, to know more about the wash water effluents from potable water treatment plants. Among them, Vianna and Ferreira [12] published results about the quality of the wash water from a PWTP which treats water with very low turbidity along great part of the year. Also, Ferreira and Vianna [5] studied the case of dewatering, through geotextile bags, the sludge formed in settling tanks of a PWTP and the wash water from its filters. As in previous papers, no association between crude water quality, chemical products dosed and solids production was studied.

Landfilling is, in most cases, the final destiny of the removed solids. Alternatives for this solution had been studied. In particular, Madureira [6] has verified the possibility of its use with clay in red ceramic industry.

Environmental pressures had been responsible for the implantation of LWTP without adequate previous studies, including those that would allow determining the quantity to be formed. The authors participated of the elaboration of the project of two of them, both for small flows. One of them produces 15 L/s of potable water, see Figure 1, and the other one produces 32 L/s, see Figure 2. Both should eliminate their liquid wastes production, as well as find a convenient destiny for their solid wastes, in order to keep their activities of supplying potable water for small cities of Minas Gerais. In this way, the solids production of these plants were roughly estimated, using generic references found in the technical literature.
Soares [10] conducted an important study concerning the solids production in Rio Manso PWTP, Minas Gerais. It is a 3.7 m³/s classic conventional-type unit (in which flash mixing, flocculation, sedimentation and filtration occur in separated units), 3.7 m³/s capacity. Figure 3 shows its schematic flow diagram. The study presents a comparison between in loco measured solids production with previsions obtained using some formulae developed for this purpose, which can be found in technical literature.

Among these formulae, a specific one has shown particular importance for its simplicity and because only two input data – alum dosing rate and turbidity – were necessary for its use. That formula is (equation 1):

\[ m = Q(0.75 \times Tu + 0.44 \times DSAI) \times 10^{-3} \quad \text{Eq. 1} \]

where:
- \( m \) = mass of solids produced (kg/day);
- \( Q \) = flow of crude water (m³/day);
- \( Tu \) = average turbidity of the crude water (uT);
- \( DSAI \) = average dosing rate of alum (mg/L).

The comparison between results measured in loco and the corresponding previsions by the formula are reproduced in table I and figure 4.
TABLE I
SOLIDS PRODUCTION (MEASURED AND PREVISIONS) IN RIO MANSO PWTP

<table>
<thead>
<tr>
<th>Month</th>
<th>Avg Q L/s (*)</th>
<th>Avg Tu uT (*)</th>
<th>Avg DSAl mg/L (*)</th>
<th>Solids production</th>
<th>Measured</th>
<th>Prevision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug/07</td>
<td>3728</td>
<td>2.75</td>
<td>21</td>
<td>2616</td>
<td>3641</td>
<td></td>
</tr>
<tr>
<td>Sep/07</td>
<td>3746</td>
<td>2.55</td>
<td>21</td>
<td>2585</td>
<td>3610</td>
<td></td>
</tr>
<tr>
<td>Oct/07</td>
<td>3830</td>
<td>2.3</td>
<td>25.5</td>
<td>2762</td>
<td>4284</td>
<td></td>
</tr>
<tr>
<td>Nov/07</td>
<td>3736</td>
<td>2.25</td>
<td>30.5</td>
<td>2923</td>
<td>4877</td>
<td></td>
</tr>
<tr>
<td>Dec/07</td>
<td>3771</td>
<td>5</td>
<td>32.5</td>
<td>4790</td>
<td>5881</td>
<td></td>
</tr>
<tr>
<td>Jan/08</td>
<td>3668</td>
<td>9.2</td>
<td>35</td>
<td>5822</td>
<td>7067</td>
<td></td>
</tr>
<tr>
<td>Feb/08</td>
<td>3800</td>
<td>18.6</td>
<td>39.5</td>
<td>7734</td>
<td>10286</td>
<td></td>
</tr>
<tr>
<td>Mar/08</td>
<td>3791</td>
<td>21</td>
<td>51</td>
<td>13626</td>
<td>12509</td>
<td></td>
</tr>
<tr>
<td>Apr/08</td>
<td>3822</td>
<td>24</td>
<td>46.5</td>
<td>11587</td>
<td>12700</td>
<td></td>
</tr>
<tr>
<td>May/08</td>
<td>3796</td>
<td>11.65</td>
<td>30.5</td>
<td>7610</td>
<td>7267</td>
<td></td>
</tr>
<tr>
<td>Jun/08</td>
<td>3758</td>
<td>6.2</td>
<td>18</td>
<td>3602</td>
<td>4081</td>
<td></td>
</tr>
<tr>
<td>Jul/08</td>
<td>3744</td>
<td>5.75</td>
<td>26</td>
<td>4148</td>
<td>5096</td>
<td></td>
</tr>
</tbody>
</table>

(*) Avg = Average

Fig. 4: Solids production (measured e calculated) in Rio Manso PWTP

Rio Manso PWTP is supplied by an artificial lake built specifically for this purpose. Its hydrographic basin is adequately protected against anthropic actions that could harm its water quality. The turbidity of the crude water presents small values during almost all the year. The higher value observed during the observation period was 24 uT. This value contrasts with the average turbidity found in rivers of Minas Gerais, which reach (or, in some cases, are higher than) 100 uT.

For this reason, it would be important to validate the results offered by the formula. Two other cases of PWTP of Minas Gerais were then selected for this purpose. Both are fed with crude waters that come from rivers, not lakes. The following items contemplate these cases.

II. CASE STUDIES

The first case examined was Morro Redondo PWTP. As in Rio Manso case, it is a classic conventional-type unit, 0.75 m³/s capacity. Figure 5 shows its schematic flow diagram. Crude water comes from three different rivers that present low turbidity during great part of the year, thus demanding small dosing rates of flocculant, see table II and figure 6. The flocculant used is alum, furnished as a commercial solution.

The cleansing of each one of its two settling basins is made once a year, when the settled sludge in their interior reaches 1.50 m approximately.

Fig. 5: Morro Redondo PWTP: schematic flow diagram

Samples of settled sludge were collected in May, 2011. The sludge was collected in distinct and symmetric points of the settling tanks as shown in figure 7 using a clamshell bucket device, see figure 8. The samples were put into 5 L recipients and sent for analysis. The total solids concentration of the homogenized sample collected in each settling tank was then analyzed by the gravimetric method recommended by the Brazilian standards [2].

Table II
Turbidity Of The Incoming Water To Morro Redondo PWTP And Flocculant Dosing Rates: Average Data Registered Between May 2010 And May 2011 [5]

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Turbidity uT</th>
<th>Dosing rate mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>May</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Jun</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Jul</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Aug</td>
<td>1.5</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Set</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Oct</td>
<td>21</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Nov</td>
<td>55</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Dec</td>
<td>74</td>
<td>23</td>
</tr>
<tr>
<td>2011</td>
<td>Jan</td>
<td>64</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Feb</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Mar</td>
<td>44</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Abr</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>May</td>
<td>2</td>
<td>14</td>
</tr>
</tbody>
</table>
Figure 9 shows pictures of the sludge samples before and after the total solid analysis. Tables III and IV show the values obtained through these essays.

**Table III**
Settled sludge collected into the settling tank 1: total solids obtained from the analysis.

<table>
<thead>
<tr>
<th>Sample point</th>
<th>Initial mass</th>
<th>Final mass</th>
<th>Total solids concentration (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31</td>
<td>7</td>
<td>22.58</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>6</td>
<td>15.00</td>
</tr>
<tr>
<td>3</td>
<td>36</td>
<td>6</td>
<td>16.67</td>
</tr>
<tr>
<td>4</td>
<td>33</td>
<td>7</td>
<td>21.21</td>
</tr>
</tbody>
</table>

Average solids concentration (%) 19

**Table IV**
Settled sludge collected into the settling tank 1: total solids obtained from the analysis.

<table>
<thead>
<tr>
<th>Sample point</th>
<th>Initial mass</th>
<th>Final mass</th>
<th>Total solids concentration (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>8</td>
<td>25.81</td>
<td>31</td>
</tr>
<tr>
<td>30</td>
<td>5</td>
<td>16.67</td>
<td>30</td>
</tr>
<tr>
<td>34</td>
<td>6</td>
<td>17.65</td>
<td>34</td>
</tr>
<tr>
<td>32</td>
<td>6</td>
<td>18.75</td>
<td>32</td>
</tr>
</tbody>
</table>

Average solids concentration (%) 20

Taking into account the internal dimensions of each settling tank as shown in figure 3 and assuming that, when the sludge was drained, its average depth over the bottom was equal to 1.50 m, as informed by the operators of the plant, then the volume of sludge stored in the period was:

\[ V = 2 \times (17 \times 52) \times 1.50 = 2652 \text{ m}^3 = 2652 \times 10^3 \text{ L} \]

Assuming that the average solids concentration of the sludge was 19.5\%, the mass of solids produced was:

\[ m = 2652 \times 10^3 \times 0.195 = 517 \times 10^3 \text{ kg} \]

The second case examined was the city of Formiga PWTP. It is also a classic conventional-type unit, 0.2 m³/s capacity. Figure 10 shows its schematic flow diagram.
Crude water comes from Formiga river which presents medium turbidity during most part of the year, thus demanding medium dosing rates of flocculant, see table 5. The flocculant used is the alum, furnished as a commercial solution.

The cleansing of each one of its two settling basins is made each two months. The settled sludge volume drained from each unit is of approximately 300 m³ (300 x 10³ L) and its concentration is approximately 10% W, as informed by the operators of the plant.

Taking into account that the concentration of the solution is 50% W. then the average consumption of alum during that period was 76599 kg.

Assuming these values, the mass of solids produced would be:
\[ m = 300 \times 10^3 \times 0.10 = 30 \times 10^3 \text{ kg} \]

### III. DISCUSSION

The purpose of this discussion is to show that the sludge production in the two cases examined are not far from the values predicted by equation (1) presented by Soares [10].

First consider the case of Morro Redondo PWTP. Using the turbidity and alum dosing rate shown in figure 4, it is possible to estimate the sludge production from June 2010 to May 2011 using equation 1. The obtained values corresponding to each month is shown in table VII.

Assuming that 90% of this volume are removed by the settling tanks (the remaining 10% will be removed by the filters), then the sludge mass retained in these units would be:
\[ m = 476 \times 10^3 \times 0.9 = 534 \times 10^3 \text{ kg} \]

Which approximates of the value 517 x 10³ kg obtained by the equation 1, as calculated in the preceding item.

Consider now the case of the city of Formiga PWTP.
The following data are necessary for the use of equation 1:

\[
Q = \text{crude water flow} = 0.2 \text{ m}^3/\text{s} \times 3600 \text{ s/h} \times 20 \text{ h/day} = 14400 \text{ m}^3/\text{day}
\]

\[
DSAI = \text{alum average dosing rate (calculated in the preceding item): } 13.3 \text{ mg/L}
\]

\[
Tu = \text{average turbidity of the crude water} = 100 \text{ UT (typical average value for waters in rivers of Minas Gerais)}
\]

Thus:

\[
m = Q (0.75 \times Tu + 0.44 \times DSAI) \times 10^{-3} = 14400 (0.75 \times 100 + 0.44 \times 13.3) \times 10^{-3} = 1164 \text{ kg/day}
\]

or, for each two months:

\[
m = 2 \times 30 \times 1164 = 69840 \text{ kg}
\]

Assuming that 90% of this volume are removed by the settling tanks (the remaining 10% will be removed by the filters), then the sludge mass retained in these units would be:

\[
m = 69840 \times 0.9 = 62856 \text{ kg}
\]

That means that each one of the two settling tanks will retain 31.3 x 10³ kg of sludge, which approximates of the value 30 x 10³ kg calculated in the preceding item.

IV. Final Considerations

Equation 1, as presented by Soares (2009) and nowadays adopted by the authors in their studies for LWTP implementation has shown, in both examined cases, to be adequate to estimate the solids production in PWTP of Minas Gerais.

It is important to notice that there are formulae that consider other input data such as dosing rates of lime, polymers and activated carbon as well as other characteristics of crude water, such as its apparent color. Nevertheless, when it is considered the reality which prevails in Minas Gerais, where the water of the rivers are usually soft, demanding low lime dosing rates for their adequate coagulation and flocculation (or in many cases, no necessity of dosing that product), then the examined equation appears to be an efficient instrument.

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REFERENCES


