[Farhaoui *, Vol.5 (Iss.2): February, 2017]
ICV (Index Copernicus Value) 2015: 71.21

ISSN- 2350-0530(O), ISSN- 2394-3629(P)
IF: 4.321 (CosmosImpactFactor), 2.532 (I2OR)
InfoBase Index IBI Factor 3.86

INTERNATIONAL JOURNAL OF RESEARCH – GRANTHAALAYAH
A knowledge Repository

Science

MANAGING AND MODELING OF THE DRINKING WATER TREATMENT PLANT SLUDGE

M. Farhaoui [*1]
[*1] National Office of Electricity and Drinking Water, Morocco

DOI: https://doi.org/10.29121/granthaalayah.v5.i2.2017.1719

Abstract

Water management is a key pillar of sustainable development. Indeed, the rational use of water has become a condition for new investments in the water sector as many sectors. Optimizing the production of drinking water is one aspect. This optimization involves not only the choice of water resource use but also the management of by-products of the water treatment process to manage sustainably the exploited water resources.
The city of Meknes is watered from two sources and a set of holes (14), the turbidity of water sources can vary depending on rainfall recorded in the region. A water treatment plant (600 l/s) was performed for the purification of water sources. Through this study, we focus on modeling of sludge volume produced by this plant. The objective is to design a model for calculating the sludge volume from the actual data recorded in the plant. The model ca be used by the operator to predict the sludge volume and can be used also by the designers.
The results of this study demonstrated that the volumes calculated from the model constructed considering the data recorded at the station perfectly match the volumes produced with a determination coefficient of 100%.
The application of this model can not only provide the operator with an effective tool for managing of the station by-products but also to provide designers with a formula to prevent over/under design of structures. Therefore, these measures help to optimize the cost of production of drinking water and will play an important role in the sustainable development of water resources.

Keywords: Sustainable Management; Coagulation; Turbidity; Sludge; Model.

CITE THIS ARTICLE: M. Farhaoui. (2017). "MANAGING AND MODELING OF THE DRINKING WATER TREATMENT PLANT SLUDGE." *International Journal of Research - Granthaalayah*, 5(2), 168-179. https://doi.org/10.29121/granthaalayah.v5.i2.2017.1719.

1. Introduction

In the drinking water treatment processes, the optimization of the treatment is an issue of particular concern [1]. In general, the process consists of many units as settling, coagulation, flocculation, sedimentation, filtration, disinfection and sludge treatment. The optimization of the process consists of some measures to decrease the managing and monitoring expenses and improve the quality of the produced water. The objective of this study is to provide water treatment operators with tool to attain the most effective managing of the facility by-products and in consequence optimize the cubic meter price of the treated water. This paper proposes a model to calculate the sludge of drinking water treatment process by analyzing all of the water treatment data. Some practical solutions and methods are performed in the water treatment plant located in the middle of Morocco (Meknes).

This paper is organized as fellows. After an introduction of the objective of this study, the water treatment operation is described in section II. Review on reuse of water treatment plant sludge is discussed in section III. In the section IV, modeling of sludge volume is explained.

2. Water Treatment Operation

Meknes region is located in the middle of Moroccan Kingdom, has a Mediterranean climate with continental influences. The temperature shifts from cool and cold in winter to hot days in the summer months of June–September. The agriculture and industry are the mean activities in the region.

This study was developed in a water treatment plant located in Meknes, whose source is two big springs Bittit (630 l/s) and Ribaa (400 l/s). The quality of water produced by the springs changes according to the rainfall in the region. Sometimes, it can be affected by the snow in the Atlas Mountains. The treatment water plant, as part of other water resources, water to more than 700.000 inhabitants of Meknes city, and it has a nominal capacity of 600 l/s of treated water. This water treatment plant is chosen regarding to the variation of the raw water turbidity and because of the availability of data. Figure 1 presents a schematic overview of the various operations necessary to treat the water.

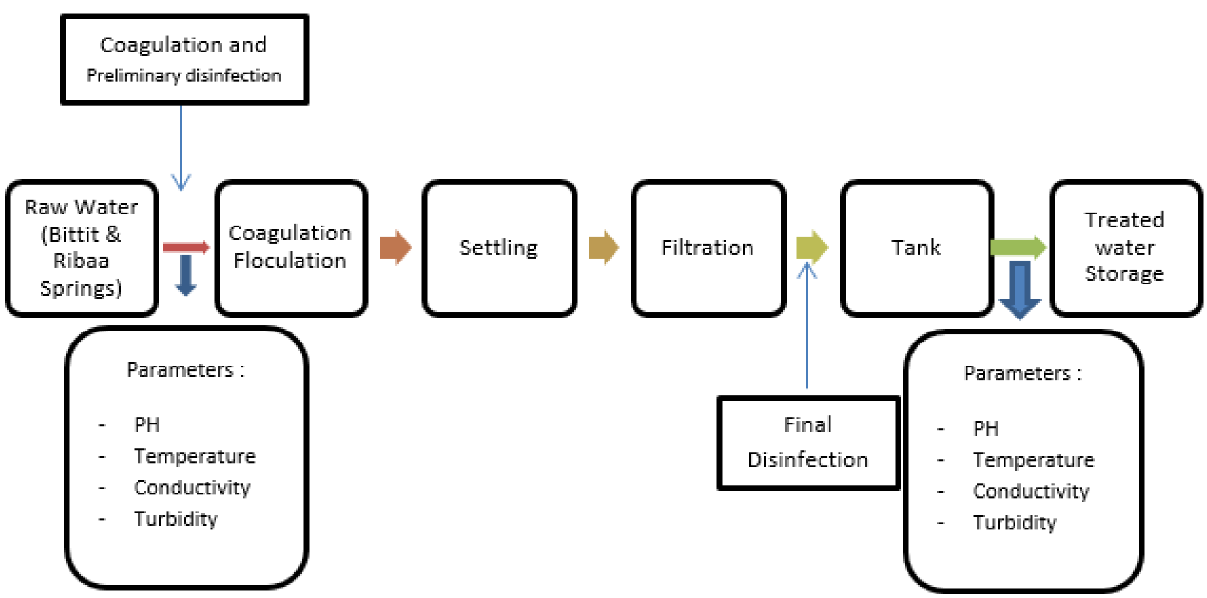


Figure 1: Simplified synopsis of the water treatment plant

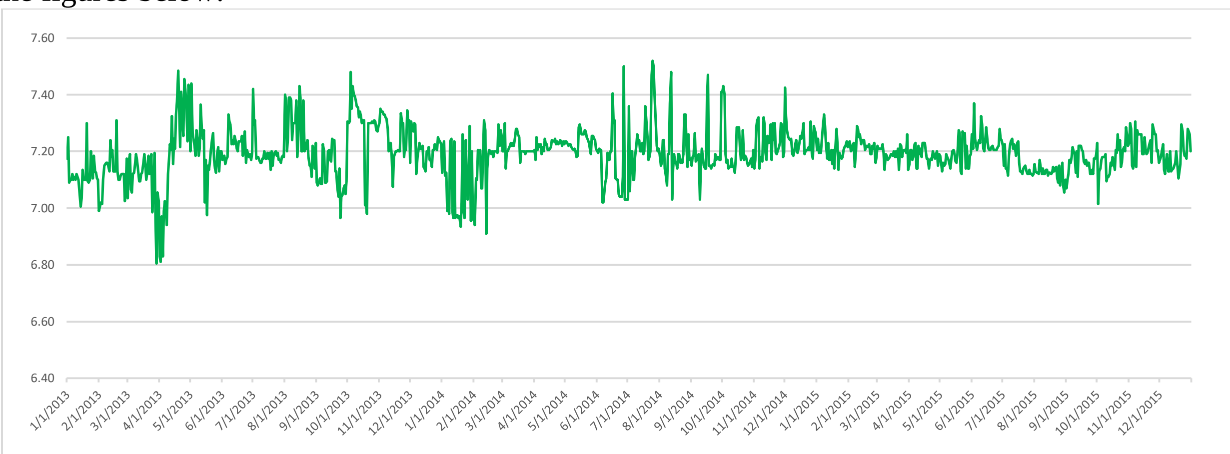
ISSN- 2350-0530(O), ISSN- 2394-3629(P)
IF: 4.321 (CosmosImpactFactor), 2.532 (I2OR)
InfoBase Index IBI Factor 3.86

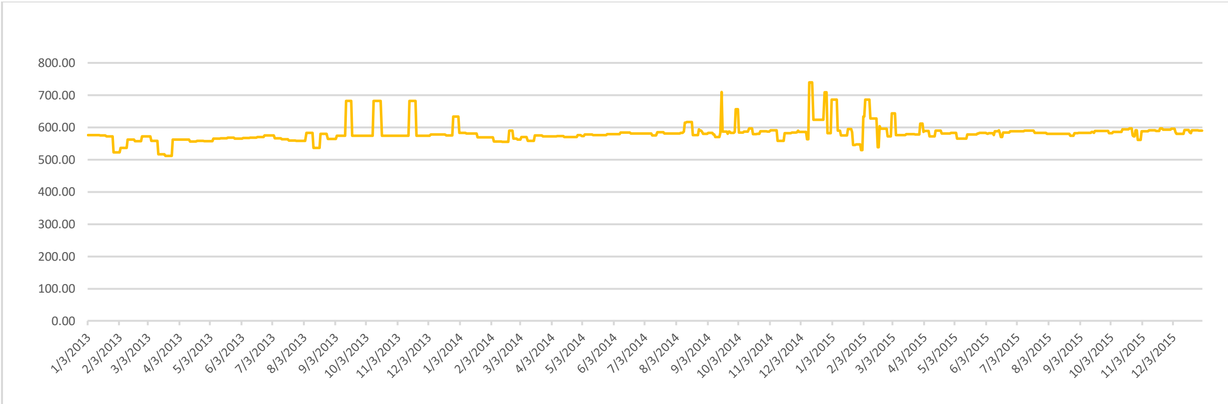
Many measurements of variables recorded by streaming current detectors such as: turbidity level, PH, conductivity, temperature is needed to carry out the jars test in order to determine the optimal dose of the aluminum sulfate. The raw water variables used in this study present the following variation intervals:

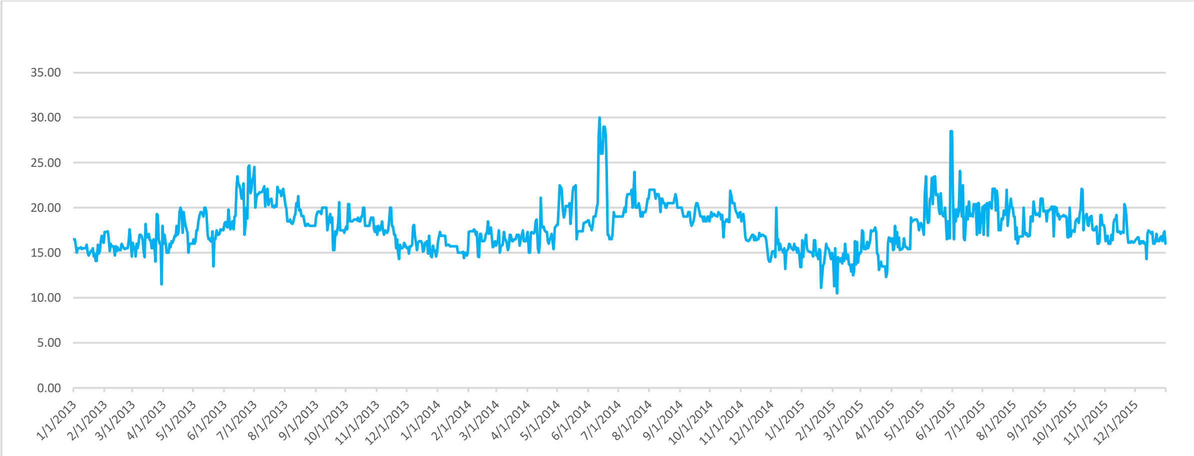
Table 1: statistical summary of raw water conditions from 01/01/2013 to 31/12/2015 (ONEE, 2015)

Variables	**Min**	**Max**
Turbidity: Bittit (NTU)	1.7	850
Turbidity: Ribaa (NTU)	1.62	960
PH	6.80	7.74
Temperature: (°C)	14	24.70
Conductivity micro s/cm	509	624

The variation of PH, conductivity and temperature from 01/01/2013 to 31/12/2015 is given by the figures below:







Figures 2: Evolution of PH (a), conductivity in micro S/cm (b) and temperature in °C (c) of raw water from 01/01/2013 to 31/12/2015

In the rainfall period, the turbidity of raw water changes from time to time as shown in the graph below, the turbidity of the raw water can increase to reach levels more than 500 NTU:

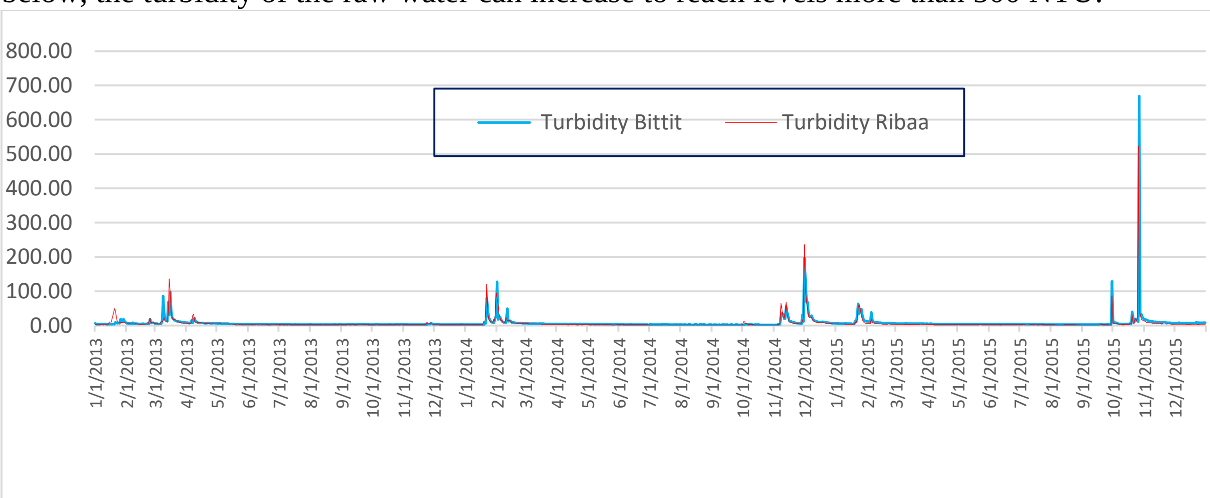


Figure 3: statistical data of turbidity level of the spring's water from 01/01/2013 to 31/12/2015 (ONEE, 2015)

However, the turbidity level is less than 10 NTU this three last years (2013, 2014 and 2015) for more than 88% of the year and more than 64% of the year (1637 /2556 days); the turbidity is less than 10 NTU for the six last years as shown by the table below.

Table 2: Turbidity levels distribution from 2009 to 2015 (Number of days per turbidity level)

	Number of days					**Total**
Year	Turbidity less or equal than 5 NTU	Turbidity more than 5and less or equal than 10 NTU	Turbidity more than 10 and less or equal than 20 NTU	Turbidity more than 20 and less or equal than 40 NTU	Turbidity more than 40 NTU	

2009	147	60	101	34	23	365
2010	0	0	113	148	104	365
2011	0	132	144	59	30	365
2012	301	38	17	5	5	366
2013	260	74	23	8	0	365
2014	247	62	32	20	4	365
2015	184	132	34	10	5	365
Total	1139	498	464	284	171	2556
Aggregated data	1139	1637	2101	2385	2556	
Percentage	**45%**	**19%**	**18%**	**11%**	**7%**	
Percentage of Aggregated data	**45%**	**64%**	**82%**	**93%**	**100%**	

Table 3 gives the max and min of raw water turbidity by month from 2013 to 2015:

Table 3: statistical data of turbidity min and max (NTU) measured in 2013, 2014 and 2015 per month (ONEE, 2015)

	Bittit Spring		Ribaa Spring	
Month	min	max	min	max
January	3.70	18.95	10.00	50.00
February	4.50	19.00	3.95	20.65
March	4.95	98.40	4.50	136.66
April	6.40	21.95	4.90	32.77
May	3.93	6.30	3.80	5.30
June	3.72	4.40	3.34	4.89
July	3.30	4.33	2.92	3.62
August	3.00	3.80	2.70	3.46
September	3.10	4.64	2.68	4.15
October	2.90	3.99	2.46	3.62
November	2.70	7.44	2.90	10.00
December	3.07	4.23	2.60	3.95
Year : 2014				
	Bittit Spring		Ribaa Spring	
	min	max	min	max
January	3.06	81.69	3.00	120.66
February	6.48	128.00	5.93	78.90
March	4.86	6.91	3.90	5.65
April	4.30	4.90	3.30	4.19

May	3.17	4.77	2,48	3.37
June	3.00	3.86	2.60	2.87
July	2.36	4.50	2.16	2.49
August	1.74	4.20	1.88	2.28
September	1.80	3.50	1.64	1.90
October	1.89	4.20	1.67	11.64
November	1.80	55.50	1.68	69.29
December	6.57	197.50	5.06	235.89
Year: 2015				
	Bittit Spring		Ribaa Spring	
	min	max	min	max
January	5.09	63.10	3.96	61.59
February	6.33	38.52	3.98	19.45
March	4.97	6.27	3.26	4.64
April	3.65	5.60	2.80	3.76
May	3.50	5.23	2.68	3.06
June	3.40	4.52	2.61	3.19
July	2.80	4.75	2.40	3.60
August	2.60	3.26	2.45	2.74
September	2.70	128.45	2.35	86.63
October	4.35	669.71	3.22	524.03
November	6.76	17.18	3.99	13.19
December	7.18	9.54	3.42	4.02

The sludge volume produced by the WTP is given in Table 4:

Table 4: statistical data of sludge volume produced by the WTP in 2013, 2014 and 2015 (ONEE, 2015)

Year	**2013**	**2014**	**2015**
Sludge volume (m3)	9559	14021	10810

3. Review on Reuse of Water Treatment Plant Sludge

The sludge produced by water treatment and sewage plants are a real problem not only for the environment but also for the stations operators [2]. Indeed, the sludge has too negative impacts on the natural environment if they are rejected directly. Besides the management of sludge generate additional charges with other operating expenses increased the price of produced water.

Also, several problems are related to sludge management regarding to the lack of laws, sludge management regulations and the lack of encouragement for investment in reuse of sludge from water treatment plants, wastewater treatment plants sewage or industrial plants.

Several studies have been performed to treasure the sludge produced both by drinking water treatment plants (WTP) by wastewater treatment plants (WWTP) [3]. Although the reuse of sludge from WWTP is of crucial importance per the organic matter it contains. In fact, the reuse of sludge has been studied in different sectors especially in the field of construction and civil engineering. The sludge reuse aspects may be considered are:

3.1.Reuse of Sludge in Brick-Making

Sludge from the water treatment plant can be reused in bricks manufacturing [4]. Chin et al (1998) [5] examined the possibility of using a mixture of sludge and ash generated by the paper industry to produce bricks that match the standards of physical characteristics and properties. Also, Chiang et al (2000) [6] proposed the use of dried sludge with agricultural residues from rice industry in the production of a new generation of bricks, this was approved by Yuh Kung et al (2009) [7] in manufacturer bricks per this mixture. Chihpin et al (2005) [8] examined the effect of the use of sludge treatment plants with soil excavation in the production of ceramic bricks. Also, Cheng-Fang et al (2006) [9] used the sludge and ash in the production of porous bricks. Badr et al (2012) [10] suggested the replacement of bricks made from clay by those made from sludge (50%), agricultural and industrial scrap (25%) and silica fume (25%) these bricks have much greater performance than ordinary bricks. In the end, Mageed A. et al (2010) [11] concluded that it is possible to make bricks from WTP's sludge (percentage of 10 to 50%) and; given the high content of organic matter in the sludge, which have several advantages not only in mitigating the problems of sludge management but also in the preservation and protection of the environment.

3.2.Reuse of Sludge in the Manufacture of Cement

The sludge produced by treatment plants can a primary component in the manufacturing of cement and concrete. Indeed, Chateveera et al (2005) [12] studied the possibility of replacement of ordinary water as a component of concrete by water sludge in the concrete manufacturing. According to this study, water sludge can substitute ordinary water from 0 to 100 % despite having a negative impact on the withdrawal after drying and acid resistance. The same result was reached by Rocaaro et al (2015) [13] proposing the reuse of sludge to partially or totally replace the water in the manufacture of concrete without any influence on the mechanical properties. Vaishali S. et al (2014) [14] proposed the reuse of sludge in construction as mortar, they proposed two types of mortar with four combinations based on the percentages of the components (ash, sludge, gypsum). Similarly, Anjithan K. et al (2015) [15] proposed to continue the investigations for the reuse of sludge in the manufacture of cement blocks and bricks for sustainable sludge reuse. Also, Alqam M. et al (2011) [16] examined the possibility of using sludge as an additive with the cement for the manufacturing of the tiles with a percentage of 10, 20, 30, 40, and 50 %, the results are very satisfactory except for those made with a percentage of 50% sludge. Furthermore, Kyncl M. (2008) [17] proposed the use, even, of sludge in the cement production process.

3.3.Reuse of Sludge in Pottery

As in construction field, WTP sludge is very important in the pottery sector. Indeed, Faris G. et al (2014) [18] proposed the use of a mixture consisting of sludge (85%) and sand (silicon dioxide) 15% in pottery manufacturing.

3.4.Reuse of Sludge in the Water Treatment and Wastewater Treatment Process

The sludge produced by the WTP can not only be reused in the construction and building sector, but also it can be reused in the WTP and WWTP process. Farhaoui M. et al (2016) [19] proposed to reuse the sludge as aid coagulant in the WTP to improve the water quality and reduce the coagulant consumption. Indeed, sludge has coagulating activity in the treatment of turbid water and can be used as coagulant or as coagulant aid with other synthetic and industrial coagulants (aluminum sulfate…) in order to reduce the coagulant consumption in the water treatment plant [13]. In the other hand, Irene N. et al (2013) [20] suggested the use of sludge from WTP as aid coagulant in flocculation to improve the sedimentation, sludge can improve the removal of suspended solids, phosphate and the total Ammonium nitrogen (TAN). Also, Abhilash T. et al (2014) [21] concluded that it is possible to reduce the consumption of coagulant in WWTP by reusing of sludge from WTP using aluminum sulphate as coagulant.

3.5.Reuse of Sludge in Agriculture

Several studies have been conducted for the reuse of sludge from WWTP in the agriculture field regarding the organic matter it contain. However, it is also possible to reuse sludge from WTP as fertilizer in agricultural activities. Verlicchi P. [22] et al have calculated the reuse of sludge in several countries in Europe and America, they have led to the possibility of reuse of sludge in agriculture and they also stressed the need for the legislation and laws readapting in order to promote the sludge reuse.

4. Modeling of WTP Sludge Volume

Some attempts have been made to model the relationship between sludge volume produced by the WTP and the aluminum sulphate consummation, turbidity, treated water volume using the recorded data given in Table 5:

Table 5: Data related to the sludge production from 2013 to 2015

Year	**Treated water Volume m3**	**Sludge volume m3**	**Aluminum sulphate consumption Kg**	**Number of days**				
				Turbidity less or equal than 5 NTU	**Turbidity more than 5and less or equal than 10 NTU**	**Turbidity more than 10 and less or equal than 20 NTU**	**Turbidity more than 20 and less or equal than 40 NTU**	**Turbidity more than 40 NTU**
2013	15098736	9559	242850	260	74	23	8	0
2014	15508924	14021	203820	247	62	32	20	4
2015	15214486	10810	149330	185	131	34	10	5

5. Methodology

The prediction of sludge volume from WTP data is a very interesting approach. The identification aims at modeling and parameter estimation. It consists of constructing a mathematical model that can describe the behavior "-Input-output" of the system. The problem is to determine the model parameters from recorded data in the WTP. The analysis of experimental data for different periods of the year in the water treatment plant allow obtain mathematical models describing the changes in sludge volume based on the input parameters of the WTP using Statgraphics software.

The model to develop will be based on the data available in the plant from 2013 to 2015. The data validation, processing and modeling of the coagulant dosage rate are the main steps to construct the model [23].

According to the data recorded in the WTP, many models are identified and analyzed using Statgraphics software which indicates the relationship between the sludge volumes measured and calculated by different models.

After the construction of the model. A statistical test is performed on model in order to evaluate how much the model fitted with the observed data.

6. Results and Discussions

After performing these steps, the developed model is:

$$V = a + b * (TWV * (A * 5 + B * 10 + C * 20 + D * 30 + 40 * E)) / N + c * TWV * SA)$$

Where,

- V is the volume of sludge produced in m3
- TWV is the annual volume of water treated in m3.
- A: The number of days per year where the turbidity is less than or equal to 5 NTU
- B: Number of days per year when the turbidity exceeds 5 and less than or equal to 10 NTU
- C: Number of days per year when the turbidity exceeds 10 and less than or equal to 20 NTU
- D: Number of days per year when the turbidity exceeds 20 and less than or equal to 40 NTU
- E: Number of days per year when the turbidity exceeds 40 NTU
- N: Number of days per year
- SA: Annual amount of alum consumed kg.
- a, b, c: Parameters to be determined.

After identifying the model, the calculated values are in perfect coordination with those measured. Indeed, the chosen model perfectly reflects the values measured with a coefficient of determination of 100% as shown in Figure.

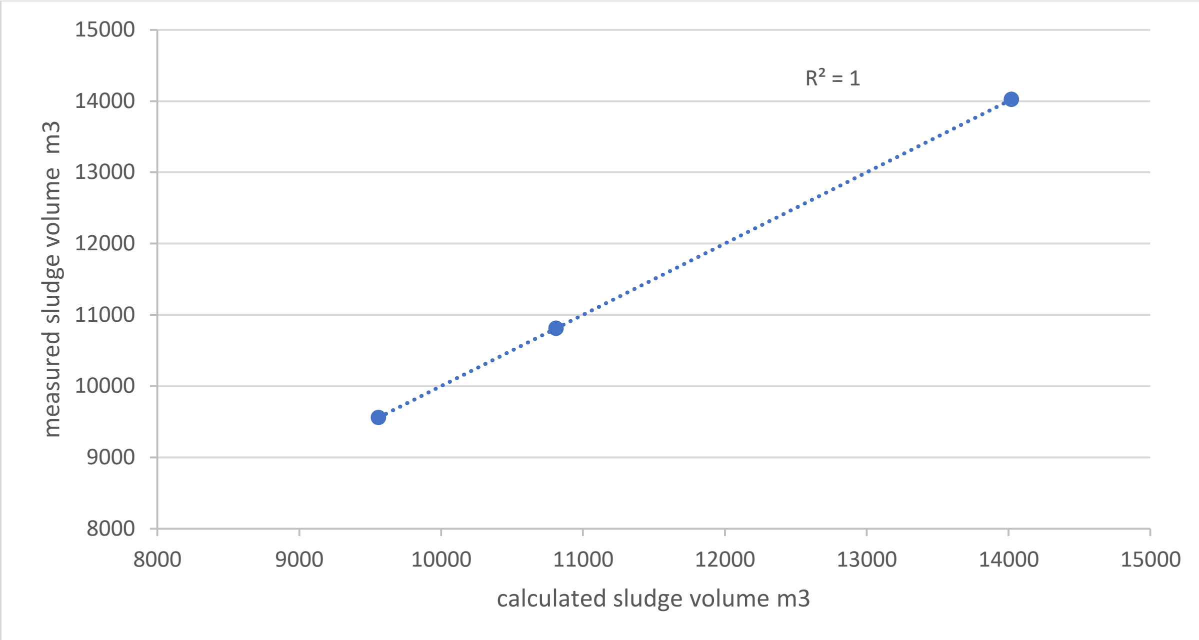


Figure 4: Relationship between measured and calculated sludge volumes

This relationship can be applied to treatment plants which treat water turbidity is low. It presents the following advantages:

- It is simple and is based on real data in relation to water quality.
- It is based on the turbidity distribution by day. Indeed, it is not based on an average of the concentration of suspended solids. Thus, the formula avoid structures overestimating.
- It introduces the actual amount of aluminum consumed by the WTP.

7. Conclusions

This paper has presented some preliminary results concerning the challenging task of modeling the sludge volume produced by the water treatment plant using model. The model is related to treated water volume, turbidity distribution par year and the aluminum sulphate consumption. The aim of the model is to provide water treatment operators with a tool that enables prediction of the sludge volume using the parameters measured in the plant. The performance of the model can be improved according to the database in the water treatment plant and updating of the data base would certainly contribute to reach the representative model for predicting sludge volume. This approach can contribute to master the WTP inputs/outputs in order to ovoid many operating problems and reduce the operations expenses. Therefore, it is reasonable to consider this approach to be applied in the treatment plant for water with similar turbidity level.

References

[1] Farhaoui, M. and Derraz, M. (2016) Review on Optimization of Drinking Water Treatment Process. Journal of Water Resource and Protection, 8, 777-786. http://dx.doi.org/10.4236/jwarp.2016.88063
[2] Nguyen Trung Viet, Tran Thi My Dieu, Nguyen Thi Phuong Loan, Current Status of Sludge Collection, Transportation and Treatment in Ho Chi Minh City, Journal of Environmental

Protection, 2013, 4, 1329-1335 Published Online December 2013 (http://www.scirp.org/journal/jep), http://dx.doi.org/10.4236/jep.2013.412154.

[3] Aeslina Binti Abdul Kadir, Ahmad Shayuti Bin Abdul Rahim, An Overview of Sludge Utilization into Fired Clay Brick, World Academy of Science, Engineering and Technology, International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering Vol:8, No:8, 2014.

[4] Anyakora Nkolika Victoria, "Characterization and Performance Evaluation of Water Works Sludge as Brick Material", International Journal of Engineering and Applied Science, vol. 3(3), pp. 69-79, May 2013.

[5] Chin, T.L., L.C. Hui, H. Wen-Ching and R.H. Chi, 1998. A novel method to reuse paper sludge and co-generation ashes from paper mill. J. Hazard. Mater., 58: 93-102.

[6] Chiang, K.Y., P.H. Chou and K.L. Chien, 2000. Novel lightweight building bricks manufactured from water treatment plant sludge and agricultural waste. A case study in Feng-Chia University, Tai-Chung, Taiwan.

[7] Kung-Yuh, C., C. Ping-Huai, H. Ching-Rou, C. Kuang-Li and C. Chris, 2009. Lightweight bricks manufactured from water treatment sludge and rice husks. J. Hazard. Mater., 171: 76-82.

[8] Chihpin, H., R.P. Jill and L. Yaorey, 2005. Mixing water treatment residual with excavation waste soil in brick and artificial aggregate making. J. Environ. Eng., 101: 272-277.

[9] Cheng-Fang, L., W. Chung-Hsin and H. Hsiu-Mai, 2006. Recovery of municipal waste incineration bottom ash and water treatment sludge to water permeable pavement materials. J. Waste Management, 26: 970-978.

[10] Badr, E.D.E.H., A.F. Hanan and M.H. Ahmed, 2012. Incorporation of water sludge, silica fume and rice husk ash in brick making. J. Adv. Environ. Res., 1: 83-96.

[11] A.A.Mageed , SH.A.Rizk, and M.H.Abu-Ali, Utilization of water treatment plant sludge ash in brick making, Journal of Engineering Sciences, Assiut University, Vol. 39, No 1, pp. 195-206, January 2011

[12] Chatveera, B., P. Lertwattanaruk and N. Makul, 2005. Effect of sludge water from ready-mixed concrete plant on properties and durability of concrete. J. Cement Concrete Compos., 28(5): 441-450.

[13] Roccaro P., Franco A., Contrafatto L. and Vagliasindi F.G.A., Use of sludge from water and wastewater treatment plants in the production of concrete: an effective end-of-waste alternative, Proceedings of the 14th International Conference on Environmental Science and Technology, Rhodes, Greece, 3-5 September 2015.

[14] Vaishali Sahu, V. Gayathri, The Use of Fly Ash and Lime Sludge as Partial Replacement of Cement in Mortar, International Journal of Engineering and Technology Innovation, vol. 4, no. 1, 2014, pp. 30-37

[15] K Anjithan, B C L Athapattu, N Ratnayake and LA Udamulla, Sludge of water treatment works: Are disposal practices sustainable, Sri Lanka Association for the Advancement of Science, Proceedings of the 71st Annual Sessions – 2015 Part I

[16] Alqam M., Ahmad Jamrah, Haya Daghlas, Utilization of Cement Incorporated with Water Treatment Sludge, Jordan Journal of Civil Engineering, Volume 5, No. 2, 2011

[17] KYNCL Miroslav, Opportunities for water treatment sludge reuse, GeoScience Engineering, Volume LIV (2008), No.1, p. 11-22.

[18] Faris Gorashi Faris, Choong Choe Earn, A New Approach to Reuse Alum Sludge in Pottery Manufacturing Using Silica and Thermal Curing, International Journal of Chemical, environmental & Biological Sciences (IJCEBS) Volume 2, Issue 3 (2014).

[19] Farhaoui M., Derraz M., (2016). Optimizing coagulation process by using sludge produced in the water treatment plant, Journal of Chemical and Pharmaceutical Research, 2016, 8(4):749-756.

[20] Irene Nansubuga, Noble Banadda, Mohammed Babu, Willy Verstraete and Tom Van de Wiele, Effect of polyaluminium chloride water treatment sludge on effluent quality of domestic

wastewater treatment, African Journal of Environmental Science and Technology, Vol. 7(4), pp. 145-152, April 2013. doi: 10.5897/AJEST2.194.

[21] Abhilash T. Nair & M. Mansoor Ahammed, Coagulant recovery from water treatment plant sludge and reuse in post-treatment of UASB reactor effluent treating municipal wastewater, Environ Sci Pollut Res (2014) 21:10407–10418, DOI 10.1007/s11356-014-2900-1

[22] Verlicchi P., Masotti L., Reuse of drinking water treatment plants sludge's in agriculture: problems, perspectives and limitations, www.sswm.info/.../VERLICCHI.

[23] Farhaoui M., Hasnaoui L., Derraz M., (2016) Optimization of Drinking Water Treatment Process by Modeling the Aluminum Sulfate Dose, British Journal of Applied Science & Technology, 17(1): 1-14. DOI: 10.9734/BJAST/2016/26840.

*Corresponding author.
E-mail address: mfarhaoui@onee.ma