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Reduction of the Biochemical Oxygen Demand of the water samples from the lower basin of the Chillon River by means of Air-Ozone MicroNanobubbles, Ventanilla - Callao

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Resumen

El vertimiento de aguas residuales domesticas e industriales es uno de los mayores problemas que afrontan los ríos, el alto nivel de contaminación afecta directamente a la vida acuática y vegetal. Los productores que viven en las cercanías del rio Chillón utilizan estas aguas para regar sus chacras de cultivos, muchos de los productos alimenticios son llevados a centros comerciales de la ciudad para luego ser consumidos por la población. Debido a ello, por esta investigación se pretende disminuir o eliminar los contaminantes mediante la medición de la Demanda Bioquímica de Oxigeno (DBO); ya que es considerado como una prueba de gran valor en el análisis de los efluentes de aguas negras o muy contaminadas. Los resultados obtenidos muestran que la muestra inicial promedio fue de 173 mg/L. luego del tratamiento a 15 minutos con Micro Nanoburbujas de aire se obtuvo 53 mg/L y con Micro Nanoburbujas de ozono se obtuvo 53 mg/L. la mejor eficiencia obtenida fue 69.36%.

Palabras clave: micro-nanoburbujas, DBO, aire, ozono, agua de rio.

Abstract

The dumping of domestic and industrial wastewater is one of the major problems facing rivers, the high level of pollution directly affects aquatic and plant life. Producers living near to the Chillon River use these waters to irrigate their farms, many of the food products are taken to shopping centers in the city and then consumed by the population. Due to this reason, this research aims to reduce or eliminate pollutants by measuring the Biochemical Oxygen Demand (BOD); since it is considered as a test of great value in the analysis of sewage effluent or highly contaminated. The results show that the mean initial sample was 173 mg/L. after treatment at 15 minutes with air Micro Nanobubbles was obtained 53 mg/L and with ozone Micro Nanobubbles was obtained 53 mg/L. The best obtained efficiency was 69.36%

Keywords: micro-nanobubbles, BOD, air, ozone, river´s water.

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1. Introduction

Water is one of the most important natural resources for life whose extraction and use has effects on the ecosystem; whereas human activity directly and indirectly influences the water cycle through waste water discharges, solid wastes and other wastes; which generate their pollution.
The Chillon River is affected by discharging product of human activity such as pig farms, garbage dumps, washing of sacks, etc .; which present elements and substances with physical, chemical and bacteriological characteristics that affect the conditions of the receiving body. From the above, it is determined that the low basin of the Chillon River is contaminated and presents values of BOD_5 that surpass the National Standard of Environmental Quality for Waters. The high level of BOD_5 affects the water quality, aquatic- flora and fauna, as well as the soil if it is used for irrigation. It is necessary manage the water in order to grantee life in Peru (ANA, 2013)

In order to reduce the level of Biochemical Oxygen Demand of wastewater, the species Eichhornia Crassipes (SOCLA, 2014), coliforms in domestic sewage, marine waters (Valverde, 2017; Agalwal et al., 2011) industrial sewage (Valverde, 2017), oils and fats (Valverde, 2017), by micro-nanobubbles (MNBs).

The Venturi type generator consists of three main parts of inlet flow, tubules and conical outlet. Cavitation occurs due to the decrease in static pressure of the pressurized fluid entering the tubular part. In the tubule part, the velocity of the fluid increases at the cost of the decrease of the static pressure. Then the gas entering the inside of tubule develops a phase between the gas flow and the liquid. When the fluid is high, a pressure in wall with a shock wave is created in the tubule. This mode MBs are generated through the gas collision with the pressure in wall developed with a shock wave. (AGARWAL et al, 2011; Valverde, 2016)

The Microbubbles (MBs) have diameter more than 100 μm, the micro-nanobubbles (MNBs) have diameter between 1 to 100 μm and the nanobubbles (NBs) have diameter less than 1 μm within the fluid field (Valverde, 2016). Microbubbles have the ability to change the normal characteristic of water (Tsuge, 2014).Microbubbles (MBs) possess special properties such as the capacity for generating free radicals (Sadatomi et al., 2007), self-pressurization, and carrying a negative charge. MNBs have now attracted attention for applications in engineering areas such as the sewage treatment of wastewater by air flotation (Choung et al 1993, Fan et al. 2010). Ozone (O_3) is a strong oxidizing agent commonly used for sterilization, virus inactivation, deodorization, bleaching (decoloration), and decomposition of organic matter (Takahashi and others 2007a).

Thermotolerant coliforms using air-ozone nanobubbles decreased from 1400 NMP / 100mL to 56 NMP / 100mL, achieving an efficiency of 96%, (BVSDE, 2006; Abate and Valverde, 2017). Air-ozone micronanobubbles can reduce coliforms in domestic residual water (Cruz & Valverde, 2016).

The micro-bubble generation technology in water is applied in Health, especially when person has cardiovascular problems (Valverde, 2016).

Biochemical Oxygen Demand (BOD) is used as an indicator of the amount of oxygen that is required for the oxidation of biodegradable organic matter present in the water sample as a result of the aerobic oxidation action (Raffo, 2014; Ramalho, 2003).

2. Materials and Methods

i) Collection of water sample

The river's water samples were collected at the intersection of the Nestor Gambeta Km. 50 Highway and the Rio Chillón basin in the Ventanilla district - Callao Province, following the indications of the Quality Monitoring National Protocol of Water from Peru.

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ii) Sample analysis in laboratory

The total volume of water used for the experiment was 120 liters. The BDO was analyzed by an accredited laboratory. Also other parameters as Temperature, pH, Turbidity, Electrical Conductivity (EC), and Dissolved Oxygen (DO) were measured.

Figure 1. Collection of samples from Chillon River

iii) Fabrication of air-ozone micro-nanobubbles (MNBs)

The research was carried out ex-situ, in laboratory, where the whole system was first assembled to generate and to use the air and ozone micro-nanobubbles in river's water. The patent obtained by Dr. Eng. Jhonny Valverde Flores was used to generate air MNBs. The schematic diagram of experimental apparatus for preparation of MNBs solutions is shown in Figure 2.

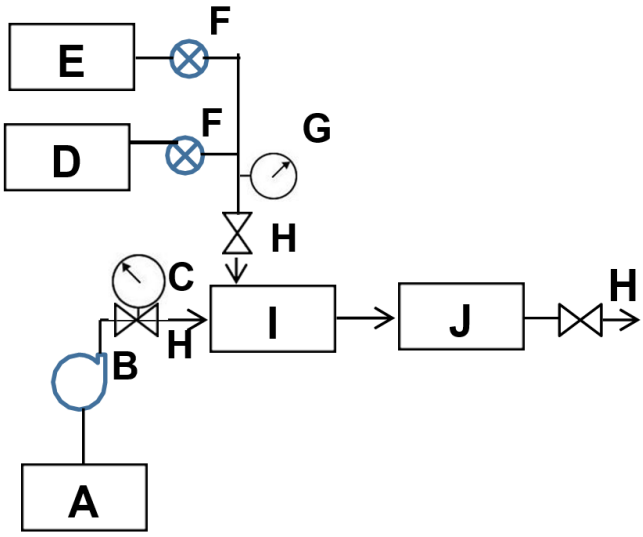

Figure 2. Schematic diagram for the river´s water treatment. Where, A: water tank, B: pump, C: flowmeter, D: air generator, E: ozone generator, F: pressure valve, G: pressure manometer, H: valve (general), I: MNBs generator, J: effluent and water with MNBs.

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The obtained average diameter of a MNB was 24 nm, the water flow was 4 L/min, the air pressure was 20 PSI.

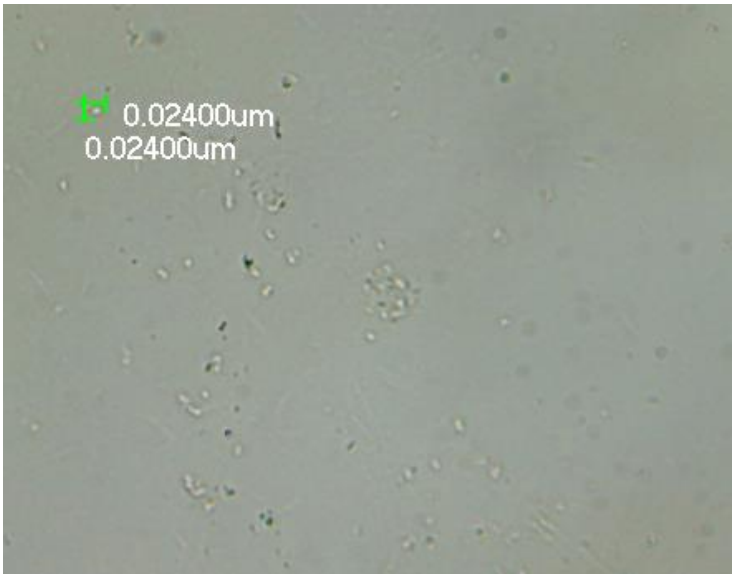

Figure 3. Average diameter of a MNB size is 24 nm

iv) Treatment of the sample

Four samples (One initial sample and three samples after treatment). Each sample was treated with air and ozone separately. The letter "A" represent Air and letter "O" represent Ozone. For example, TA1 represent treatment 1 with air and TO1 represent treatment 1 with ozone.

v) Treatment's efficiency in laboratory

Results of the samples in different concentrations were analyzed after of using air micro-nanobubbles.

To measure the MNBs treatment's efficiency on BOD was used the equation 1:

$$\%\, Remotion(BOD) = \frac{[BOD]_{initial} - [BOD]_{end}}{[BOD]_{initial}} * 100 \qquad (1)$$

3. Results and discussion

3.1. Treatment of Samples

The BOD and other parameters from river's water before and after of treatment are described in the following Tables.

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Table 1. Results of Initial Parameters from Initial Samples (1, 2 and 3)

Initial Sample	Parameter	Initial results	Unit
Initial Sample 1	pH	7.22	Unit of pH
	Temperature	22.7	°C
	Electrical Conductivity	1215	µS/cm
	Dissolved Oxygen (DO)	0.7	≥5 (minimum value)
	BOD	176	mg/L
	Turbidity	96.5	NTU
Initial Sample 2	pH	7.08	Unit of pH
	Temperature	22.7	°C
	Electrical Conductivity	1222	µS/cm
	Dissolved Oxygen (DO)	0.63	≥5 (minimum value)
	BOD	170	mg/L
	Turbidity	95.1	NTU
Initial Sample 3	pH	7.08	Unit of pH
	Temperature	22.7	°C
	Electrical Conductivity	1228	µS/cm
	Dissolved Oxygen (DO)	1.08	≥5 (minimum value)
	BOD	173	mg/L
	Turbidity	66.7	NTU
Average Initial Sample	pH	7.13	Unit of pH
	Temperature	22.70	°C
	Electrical Conductivity	1221.67	µS/cm
	Dissolved Oxygen (DO)	0.80	≥5 (minimum value)
	BOD	173.00	mg/L
	Turbidity	86.10	NTU

The results obtained from Initial Sample 1 were: pH (7.22), temperature (22.7 ºC), Electrical Conductivity (1215 µS/cm), Dissolved Oxygen (0.7), BOD (176 mg/L) and Turbidity (96.5 NTU). The results obtained from Initial Sample 2 were: pH (7.08), temperature (22.7 ºC), Electrical Conductivity (1222 µS/cm), Dissolved Oxygen (0.63), BOD (170 mg/L) and Turbidity (95.1 NTU). The results obtained from Initial Sample 3 were: pH (7.08), temperature (22.7 ºC), Electrical Conductivity (1222 µS/cm), Dissolved Oxygen (1.08), BOD (173 mg/L) and Turbidity (66.7 NTU). The results obtained from average Initial Sample were: pH (7.13), temperature (22.7 ºC), Electrical Conductivity (1221.67 µS/cm), Dissolved Oxygen (0.8), BOD (173 mg/L) and Turbidity (86.1 NTU). The average initial sample was used for treatments. See Table 1.

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Table 2. Results of TA1 and TO1

Sample	Treatment	Type of gas	Time	Parameter	Results	Unit
Average Initial Sample	TA1	Air	5 Minutes	pH	7.12	Unit of pH
				Temperature	21	°C
				Electrical Conductivity	1435	µS/cm
				Dissolved Oxygen (DO)	1.16	≥5 (minimum value)
				BOD	68	mg/L
				Turbidity	30.2	NTU
			10 Minutes	pH	7.26	Unit of pH
				Temperature	21	°C
				Electrical Conductivity	1548	µS/cm
				Dissolved Oxygen (DO)	0.86	≥5 (minimum value)
				BOD	64	mg/L
				Turbidity	57.7	NTU
			15 Minutes	pH	7.3	Unit of pH
				Temperature	21	°C
				Electrical Conductivity	1512	µS/cm
				Dissolved Oxygen (DO)	0.45	≥5 (minimum value)
				BOD	60	mg/L
				Turbidity	63.4	NTU
	TO1	Ozone	5 Minutes	pH	7.46	Unit of pH
				Temperature	21.4	°C
				Electrical Conductivity	1587	µS/cm
				Dissolved Oxygen (DO)	0.88	≥5 (minimum value)
				BOD	80	mg/L
				Turbidity	64.8	NTU
			10 Minutes	pH	7.39	Unit of pH
				Temperature	21.7	°C
				Electrical Conductivity	1593	µS/cm
				Dissolved Oxygen (DO)	0.66	≥5 (minimum value)
				BOD	60	mg/L
				Turbidity	62.7	NTU
			15 Minutes	pH	7.47	Unit of pH
				Temperature	21.6	°C
				Electrical Conductivity	1553	µS/cm
				Dissolved Oxygen (DO)	1.10	≥5 (minimum value)
				BOD	53	mg/L
				Turbidity	79.5	NTU

The results obtained from TA1 until 15 minutes were: pH (7.13), temperature (21 ºC), Electrical Conductivity (1512 µS/cm), Dissolved Oxygen (0.45), BOD (60 mg/L) and Turbidity (63.4 NTU). The results obtained from TO1 until 15 minutes were: pH (7.47), temperature (21.6 ºC), Electrical Conductivity (1553 µS/cm), Dissolved Oxygen (1.10), BOD (53 mg/L) and Turbidity (79.5 NTU). See Table 2.

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Table 3. Results of TA2 and TO2

Sample	Treatment	Type of gas	Time	Parameter	Results	Unit
Average Initial Sample	TA2	Air	5 Minutes	pH	7.14	Unit of pH
				Temperature	21.7	°C
				Electrical Conductivity	11.24	µS/cm
				Dissolved Oxygen (DO)	1.03	≥5 (minimum value)
				BOD	66	mg/L
				Turbidity	29.4	NTU
			10 Minutes	pH	7.27	Unit of pH
				Temperature	21.6	°C
				Electrical Conductivity	1114	µS/cm
				Dissolved Oxygen (DO)	0.82	≥5 (minimum value)
				BOD	63	mg/L
				Turbidity	53.6	NTU
			15 Minutes	pH	7.3	Unit of pH
				Temperature	21.4	°C
				Electrical Conductivity	1119	µS/cm
				Dissolved Oxygen (DO)	0.58	≥5 (minimum value)
				BOD	59	mg/L
				Turbidity	60.7	NTU
	TO2	Ozone	5 Minutes	pH	7.28	Unit of pH
				Temperature	21.4	°C
				Electrical Conductivity	1637	µS/cm
				Dissolved Oxygen (DO)	0.40	≥5 (minimum value)
				BOD	84	mg/L
				Turbidity	75.3	NTU
			10 Minutes	pH	7.44	Unit of pH
				Temperature	21.5	°C
				Electrical Conductivity	1645	µS/cm
				Dissolved Oxygen (DO)	1.67	≥5 (minimum value)
				BOD	68	mg/L
				Turbidity	82.1	NTU
			15 Minutes	pH	7.38	Unit of pH
				Temperature	21.3	°C
				Electrical Conductivity	1636	µS/cm
				Dissolved Oxygen (DO)	0.31	≥5 (minimum value)
				BOD	58	mg/L
				Turbidity	76.4	NTU

The results obtained from TA2 until 15 minutes were: pH (7.3), temperature (21.4 ºC), Electrical Conductivity (1119 µS/cm), Dissolved Oxygen (0.58), BOD (59 mg/L) and Turbidity (60.7 NTU). The results obtained from TO2 until 15 minutes were: pH (7.38), temperature (21.3 ºC), Electrical Conductivity (1636 µS/cm), Dissolved Oxygen (0.31), BOD (58 mg/L) and Turbidity (76.4 NTU). See Table 3.

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Table 4. Results of TA3 and TO3

Sample	Treatment	Type of gas	Time	Parameter	Results	Unit
Average Initial Sample	TA3	Air	5 Minutes	pH	7.4	Unit of pH
				Temperature	21.5	°C
				Electrical Conductivity	1238	µS/cm
				Dissolved Oxygen (DO)	2.32	≥5 (minimum value)
				BOD	66	mg/L
				Turbidity	27.6	NTU
			10 Minutes	pH	7.4	Unit of pH
				Temperature	21.5	°C
				Electrical Conductivity	1234	µS/cm
				Dissolved Oxygen (DO)	1.23	≥5 (minimum value)
				BOD	60	mg/L
				Turbidity	43.1	NTU
			15 Minutes	pH	7.41	Unit of pH
				Temperature	21.6	°C
				Electrical Conductivity	1241	µS/cm
				Dissolved Oxygen (DO)	1.37	≥5 (minimum value)
				BOD	57	mg/L
				Turbidity	46.2	NTU
	TO3	Ozone	5 Minutes	pH	7.42	Unit of pH
				Temperature	21.6	°C
				Electrical Conductivity	1614	µS/cm
				Dissolved Oxygen (DO)	1.69	≥5 (minimum value)
				BOD	78	mg/L
				Turbidity	32.7	NTU
			10 Minutes	pH	7.43	Unit of pH
				Temperature	21.6	°C
				Electrical Conductivity	1617	µS/cm
				Dissolved Oxygen (DO)	1.07	≥5 (minimum value)
				BOD	67	mg/L
				Turbidity	36.0	NTU
			15 Minutes	pH	7.48	Unit of pH
				Temperature	21.6	°C
				Electrical Conductivity	1615	µS/cm
				Dissolved Oxygen (DO)	1.55	≥5 (minimum value)
				BOD	57	mg/L
				Turbidity	34.0	NTU

The results obtained from TA3 until 15 minutes were: pH (7.41), temperature (21.6 ºC), Electrical Conductivity (1241 µS/cm), Dissolved Oxygen (1.37), BOD (57 mg/L) and Turbidity (46.2 NTU). The results obtained from TO3 until 15 minutes were: pH (7.48), temperature (21.6 ºC), Electrical Conductivity (1615 µS/cm), Dissolved Oxygen (1.55), BOD (57 mg/L) and Turbidity (34 NTU). See Table 4.

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3.2. Treatment's efficiency in laboratory

To calculate treatment's efficiency with air MNBs on BOD in TA1 as % Remotion was used the equation1:

$$\% \text{ remotion (TA1)} = (173 - 60)*100/\ 173 = 65.32\ \%$$

Then was calculated the TA2 and TA3. As a resume the efficiency is seen in table 5.

Table 5. Efficiency of treatments with air MNBs (1, 2 and 3)

Sample	BOD (mg/L)	EF (%)
Average initial sample	173	
TA1	60	65.32
TA2	59	65.90
TA3	57	67.05

The efficiency of air MNBs on river's water in TA1 was 65.32%, in TA2 was 65.90% and in TA3 was 67.05%.

To calculate treatment's efficiency with ozone MNBs on BOD in TO1 as % Remotion was used the equation1:

$$\% \text{ remotion (TO1)} = (173 - 60)*100/\ 173 = 65.32\ \%$$

Then was calculated the TO2 and TO3. As a resume the efficiency is seen in table 6.

Table 6. Efficiency of treatments with ozone MNBs (1, 2 and 3)

Sample	BOD (mg/L)	EF (%)
Average initial sample	173	
TO1	53	69.36
TO2	58	66.47
TO3	57	67.05

The efficiency of air MNBs on river's water in TO1 was 69.36%, in TO2 was 66.47% and in TO3 was 67.05%

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4. Conclusions

- There are reductions of BOD in river's water. The average initial sample was 173 mg/L of BOD, after applying the air micro-nanobubbles, the BOD was reduced to 57 mg/L in TA3 and after applying the ozone micro-nanobubbles, the BOD was reduced to 53 mg/L in TO1.
- The treatments were obtained from different times. The BOD at all of treatment achieve in of the admissible maximum value to effluents from treatment plants related to surface water, which is 100 mg/L.
- The best treatment reduction Efficiency of BOD in river's water was in TO1 by applying ozone micro-nanobubbles. It was obtained 69.36% for BOD.

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References

Abate B, Valverde J. 2017. Reduction of thermotolerant coliforms present in the sea water by means of micro-nanobubbles of air-ozone of the beach Los Pavos, Lima, Peru. Journal of Chemical engineering Transactions, Italy. Volume 60, 2017. ISBN 978-88-95608-47-1, ISSN 2283-9216.

Agarwal, Ashutosh, NG Jern, Wun and LIU Yu. 2011. Principle and applications of microbubbles and Nanoburbujas technology for water treatment. ScienceDirect. [online]. June, 2011, vol.84. [date of consultation: 30 October 2016]. Available at: http://ac.els-cdn.com/S0045653511006242/1-s2.0-S0045653511006242main.pdf? Ti id = 48cdf7ae-a371-11e6-81f9 0000aacb35e & acdnat = 1478361943 1b348f 0bbf6b2a71f2983d6d1b6d72c3

ANA. 2013. National Plan from hydric resources. Lima, Peru. . [Accessed 10.04.2017]. Available at: http://extwprlegs1.fao.org/docs/pdf/per147883anx.pdf

BVSDE. 2006. Quality Guide for beverage. [Accessed 18.03.2017]. Available at: http://www.bvsde.paho.org/CD-GDWQ/docs_microbiologicos/Indicadores%20PDF/Ecoli_bacterias_termo.pdf

Choung J, Luttell GH, Yoon RH: Characterization of operating parameters in the cleaning zone of microbubble column flotation. Int J Mineral Process 1993, 39:31-40.

Cruz R. & Valverde J.. 2017. Reduction of Coliforms presents in domestic residual waters by Air-Ozone Micro-Nanobubbles In Carhuaz city, Peru. Nanoworld Conference-2017. Boston, USA.
.
Fan M, Tao D, Honaker R, Luo Z: Nanobubble generation and its application in froth flotation (part I): nanobubble generation and its effects on properties of microbubble and millimetre scale bubble solutions. Mining Sci Technol. 2010. 20:1-19.

Raffo, E. and Ruiz, E. 2014. Characterization of wastewater and biochemical oxygen demand. ISSN: 1810-9993

Ramalho, R. Sewage treatment. Reverte, Barcelona, 1991

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Sadatomi, M., A. Kawahara, et al. 2007. An advanced microbubble generator and its application to a newly developed bubble-jet-type air-lift pump. Multiphase Science and Technology. 19(4): 323-342.

SOCLA, Wendy. Use of the species *Eichhornia Crassipes* Vegetable to reduce the level of Biochemical Oxygen Demand of the wastewater of Paramonga, Lima-2014. Thesis to obtain the Professional Degree of Environmental Engineering Lima, Peru: Universidad Cesar Vallejo.

Takahashi M, Chiba K, Li P. 2007a. Free-radical generation from collapsing microbubbles in the absence of a dynamic stimulus. J Phys Chem. B 111:1343–7.

Tsuge, H. 2014. Micro and nanobubbles: fundamentals and applications. Pan Stanford Publishing. ISBN:978-981-4463-11-9

Valverde, J. 2016. Nanotechnology for the Environmental Engineering. In: First International Congress in environmental Engineering oriented to environmental technologies: 6th to 11th October. Lima, pp. 26.

Valverde, J. 2017. Advances of Micro-Nanobubbles in wastewater. In: First Regional Congress from Students of Environmental Engineering. UNMSM, Lima-Peru: 5th to 10th June 2017.