Sludge Treatment Analysis in Potable Water Treatment Plant (PWTP) in Logroño (Spain)

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In a Drinking Water Plant the first step in purifying water is the removal of the suspended solids and other organic or inorganic compounds (silts, clays and very fine particles). The separation is based on settling processes that is carried out through coagulation and sand filtration and the resultant product in the process is sent to sludge line. In this line, the sludge is flocculated, decanted and then thickened. As the water obtained is recirculated to first-stage treatment, the concentrated sludge is dehydrated for later use.
The sludge contains a large amount of flocculants and as a result, the sludge recirculation would be possible so as to reduce the dosages of the chemical polymer streamlining the process of dehydration.
This study shows the inefficiency of the sludge recirculation, and therefore proposes sludge removal process for future designs and sludge lines projects.

1. Introduction

A Potable Water Treatment Plant (PWTP) not only produces drinking water but it is also considers as a solids generator. The water that comes to the stations (PWTP) for human consumption contains some substances which are in form of suspension and dissolved soluble materials as well as the waste produced by coagulants and other chemical reagents used in the purification process.
As these substances are retained within the in the water that needed to be purified at the station, a semi-solid residue (sludge) is formed as a result and therefore will need to be eliminated. Basically, sludge at the station is formed in the water through any of these means as shown below here (Westerhoff, 1978);

- Clay, silt and sand with reduced grain size;
- Waste of coagulation and / or flocculation mainly generated in the process of decanting and filtering;
- Possible residues of softening processes;
- Waste by activated carbon (if the powdered carbon is used in the treatment process).

Water treatment plants that employ the conventional processes of coagulation, flocculation and sedimentation produce large quantities of sludge and Qasim et al., (2006) suggested that the volume of generated sludge can be as high as 2 % of the total volume of water treated, and the use of water treatment plant sludge for various industrial and commercial manufacturing processes has been seen in most part of the world including the USA and the UK (Victoria, 2013), hence as studied previously (Anyakora et al, 2012) asserted mineralogical composition of the water treatment sludge being close to that of clay, which therefore encourages the use of water treatment sludge in brick manufacture.
The characteristics of this sludge depend essentially on the quality of raw water and the treatment applied at the station (PWTP), which for example, as considered primary sludge formed in the PWTP decanters consist primarily of aluminium oxides or iron together with materials of organic and inorganic nature (Sandoval et al., 2008). Most of these sediments are very stable and must be removed periodically from the decanters. The sludge generated by the runoff of surface waters which directly comes to the station; PWTP are largely made from inorganic materials such as clays, sands and silts. The compositions of the sludge from the filters are very similar to those contained in the bottom of the decanter, although its concentration is less when mixed with the cleaning water. Hence, these types of sludge from washing the filters are called secondary sludge. Some years back this station was only managed through the removal of sludge contained in the water, but now, due to more restrictive legislative measure being in place, new improvements to treat this sludge therefore require that the solid matter content are removed, thereon generates clean effluent which can be discharged into the public domain for the irrigation of parks and gardens. Furthermore, because the filters in biological development can be assisted, the water used in the washing of these filters can contain a larger amount of organic matter that purges from decanters.

For this reason, it is very common that the water from the washing of these filters is treated and can be done in four ways as highlighted here, such as; recycled, recovery through sending it for treatment from the start, discharging it directly into the general drainage or sending it to outside plant treatment. This is comparable to the removal of arsenic from groundwater through adsorption process. These are very dependent on the surface area of the materials and their surface chemical properties; hence iron and aluminum oxides and hydroxides have been shown to be very efficient in removing As(III) and As(V) (Glocheux et al., 2013)

In the treatment plants otherwise called "annexed", the sludge from the purges of the decanters are subjected to a treatment this is required so as to remove its moisture and then have it converted into a solid compound which could be a potential recyclable product, offering one of the greatest commercial potential for reuse (Rensburg and Morgenthal, 2003) and in the same way, another analysis showcased the potential of incorporating aluminum and ferric coagulant sludge in various manufacturing processes including clay brick making (Goldbold et al., 2003)

This paper therefore shows a study of the treatment by recycling sludge at the head of the plant which then results in no performance in sludge dehydration as well as improving the treated water clarification.

2. Process and Problems of PWTP

The drinking water plant for the treatment of sludge is not overly complex; hence in the first phase of treatment, the water is stored in an equalization tank, pond or rolling pond so as to enable the other equipment operation of the plant to continue without any barrier. Subsequently, the stored water passes on to a device otherwise known as floculador-thickener, where the sludge is concentrated.

The thickener is therefore responsible for the sludge concentration, and then through a system of electrical pumps or gravity application, the concentrated sludge is passed on to the dewatering equipment where the sludge is dried up eventually. The dewatering sludge as part of the process in the treatment of water is performed in the so-called sludge lines mainly through four distinct ways, such as; centrifugation, filter press, belt filter and drying beds. The design of these lines of sludge called "annexed" to the PWTP is based on environmental principles as well as economic and administrative accordance with respect to the watershed.

These as indicated in Table 1 are the input and output of treated water in the PWTP Logroño city of Spain in the period 1997 - 2001.

Table 1: Data input and output of water in the PWTP of Logroño City [M = Mega (10^6)]

Year	Raw water m^3 (M)	Potable water m^3 (M)	Consumptive Water m^3 (M)	Purged water in decanters m^3 (M)	Washing Water from filters m^3 (M)
1998	16.22	14.25	1.97	1.31	0.66
1999	17.65	15.62	2.03	1.24	0.79
2000	18.10	15.77	2.32	1.72	0.61
2001	18.09	15.87	2.21	1.54	0.67
2002	20.43	18.21	2.22	1.43	0.79
Total	90.48	79.72	10.75	7.24	3.52

From the Table 1 above, it was deduced that in four years, the total volume of water that entered the PWTP was equivalently 90.48 Mm^3 and of which 10.75 Mm^3 were poured or evacuated to the existing irrigation ditch in the vicinity of the station, in the Iregua River, or in the dam of Grajera for agricultural purposes.

The resultant was calculated through the difference between the two values and gives 79.72 Mm^3 of potable water which was generated from the provincial water station to Logroño city and its environs of the surrounding towns (Lardero, Villamediana and Alberite), for human consumption, industry and various public uses (cleanings streets and irrigation of parks and public gardens etc.).

Another conclusion that can be derived from Table 1 is that the volume of water needed to clarify and wash the filters (wasting water) amounted to 10.75 Mm^3 in that period.

Likewise, 7.24 Mm^3 were used to purge water in decanters and remove the sludge precipitates and 3.52 Mm^3 were used to wash filters. These filters wash water were then transferred directly to Grajera dam and canals network in the vicinity of the company and due to the reduction of the concessional fee for Iregua river catchment and the obligation to reduce the operating costs of the water station (PWTP) in Logroño, a new header recirculation line was proposed and constructed in 2002 which was set to be a by passer to the previous one as a way to improve the plant.

3. New Line Proposed for Logrono PWTP in the Year 2002

The new line proposed for the Potable Water Treatment Plant (PWTP) in Logroño was formed so as to have water storage area for regulated and also to control the flow in treatment or homogenization tank (Figure 1), a decanter for clarify the sludge and an equipment formed by electric pumps to send the water treated at the head of the PWTP all together were proposed to improvise for then existing one (Dytras, 2002).
Moreover, part of the thickened sludge was recirculated through two electric pumps of eccentric theme of variable flow in order to increase process efficiency.

Figure 1: Homogenization tank for the PWTP of Logrono

This sludge line was designed to remove and dry the sludge generated in the process of settling and filtrating, and thus, will assist in reducing the costs of transport to landfill. The equipment installed in this new sludge line were made up of a thickener, dehydration area, sludge recirculation line, a transmission line through electric pumps as well as sludge storage hopper.

3.1 Process Result: Mass balance (July - December 2002)

In interpreting the data shown below here, it is of importance to consider that the data were taken at installation of the said equipment, making it evident that the experience and expertise provides significant improvements in the overall performance of dehydration.
Furthermore, during the cleaning of the decanters, the sludge line was out of service for 12 days at least, and in the same vein, the facility were always considers to be out of service on Sundays. Table 2 shows the results of a controllable mass of sludge line done between the months of July to December, in the year 2002.
From these data it follows that the performance in the recovery of water supply for human consumption or irrigation water for city gardens were almost equated to 100 % and, the state of dryness of the sludge then thus exceeded 20 % according to the design of the new line that has been planned then.

Table 2: Mass balance in the new line projected for 2002 year (July - December) [M = Mega (10^6)]

Raw water m^3 (M)	Purged water in decanters m^3 (M)	Washing Water from filters m^3 (M)	Dehydrated sludge volume m^3	Water volume restored m^3 (M)	Volume of water in dehydration m^3
11.10	0.86	0.39	1,042	1.25	5,215

3.2 Study of Physicochemical Variables (2005 - 2007)

Also of consideration in this paper was to study how the sludge recirculation had influences in the thickener with respect to the number of physicochemical variables that has been studied. It is known that percentage value wherein recirculation sludge flow forwarded to the decanter with respect to the total sludge. The percentage (%) of this recirculation sludge flow was invariably sent to the two centrifugal line located in sludge dewatering.
From the analysis, the sludge is thought to be enriched with anionic polymers and that by this assumption the sludge recirculation can be improved through the sludge dryness, clarification of the treated water, reduction of the polyelectrolyte consumption as well as reducing the aluminium of drained water.
Besides, it was assumed that the recirculation proposed will substantially improve the reduction in the operating costs of the PWTP as this would make it necessary to cut down the amount of anionic polyelectrolyte in flocculation as well as that of cationic polyelectrolyte in dehydration. Also, the drainage water

could be sent to the head of the plant for reuse in the PWTP due to a low concentration of aluminium that would eventually result.

Table 3 are shows the percentages of thickened sludge recirculation and recirculated or shipped back to the decanter (10 %) in the period between 2005 and 2007. Likewise, the physicochemical variables are registered for a period of 5-7 d and also, in Table 4 are shown the values of the physico-chemical variables studied during the period 2005 to 2007 against the sludge recirculation rates of 5, 10, 15, 17, 20, 22, 25, 27 and 40 % taken at different points as the new line project on the PWTP were being implemented.

4. Results / Conclusion

Below shows a statistical study with the objective of investigating the influence of the recirculation of sludge with the most important physicochemical variables studied in the PWTPs. Figure 3 shows a graph multivariate which follows as the variable "% of recirculation of sludge" and the variable "Duration of the recirculation" remained constant. Also in Figure 4 shows that the variable "Flocculation polymer dosing" and the variable "Runoff water in sludge" have also remained constant. From these two figures, (Figure 3 and 4); it is deduced that the thickened sludge recirculation in the waters line of the PWTP in Logroño is fully dispensable in the water purification process. This malfunction in the recirculation of sludge in this PWTP may be due primarily to improper sludge concentration and its biological contaminants. The sludge must not contain a very high concentration for proper operation and must be less than 0.5 % overall.

Another parameter which can affect the efficiency of the recirculation of sludge may be due to geological characterization of the watershed from which the water outlets for purification, especially the type of silt and clay in the mixture. For this reason, the recirculation of sludge in the PWTP should generally be ignored and the future designs of such facilities should then systematically consider sending thickened sludge dehydration directly without recirculation.

Figure 2: Centrifuges for dewatering sludge

Table 3: Planning and recirculation criterion data collection in PWTP for 10 % of recirculation

	Trial Period	Recirculation time and % recirculation
2	31/10 /2005 15/03 - 19/03/2007	5 – 60/s 10
6	5 – 25 2000 – 12000	10 – 60/s 10
15	28/03 - 31/03/2006 23/01 - 24/01/2007	20 – 60/s 10
20	15/05 - 19/05/2006 07/02 - 09/02/2007	25 – 60/s 10

Table 4: Variables studied in the sludge line of the PWTP

Phases of the process	Variable name	Variable code	Range	Units of Measure
Untreated water input	Untreated water	Vol_B	400 – 5,000	m^3/day
	Turbidity	NTU_B	20 – 4,600	NTU
	Flocculation	FLOC_B	5 – 25	ppm
	Aluminium	AL_B	2,000 – 12,000	ppb

	Settleable Solids	SS_B	10 – 1,000	ppm
Sludge treatment	Centrifuged Turbidity of Water	NTU_C	0.25 – 2.00	NTU
	Aluminium water centrifuged	AL_C	200 – 20,000	ppb
	Dry Sludge	SeqF	10 – 25	%
	Water Centrifuged	VolSC	1 – 250	m^3
	Recirculation	Recir	5 – 120	%
Treated water output	Turbidity Output	NTUSC	6.00 – 900.00	NTU
	Aluminium output	ALSC	10 – 200	ppb
Sludge Dewatering	Poly flow rotameter	Qrpolicentr	400 – 1,000	l/h
	Sludge flow	Qfango	0.5 – 1.5	l/s
	Poly concentration	Cpoli	2.0 – 2.4	g/L
	Poly dose	Dpolicentrif	0.200 – 0.600	g/L

Figure 3: Multivariable correlation of the variables used in the process in relation to the different times and recirculation values

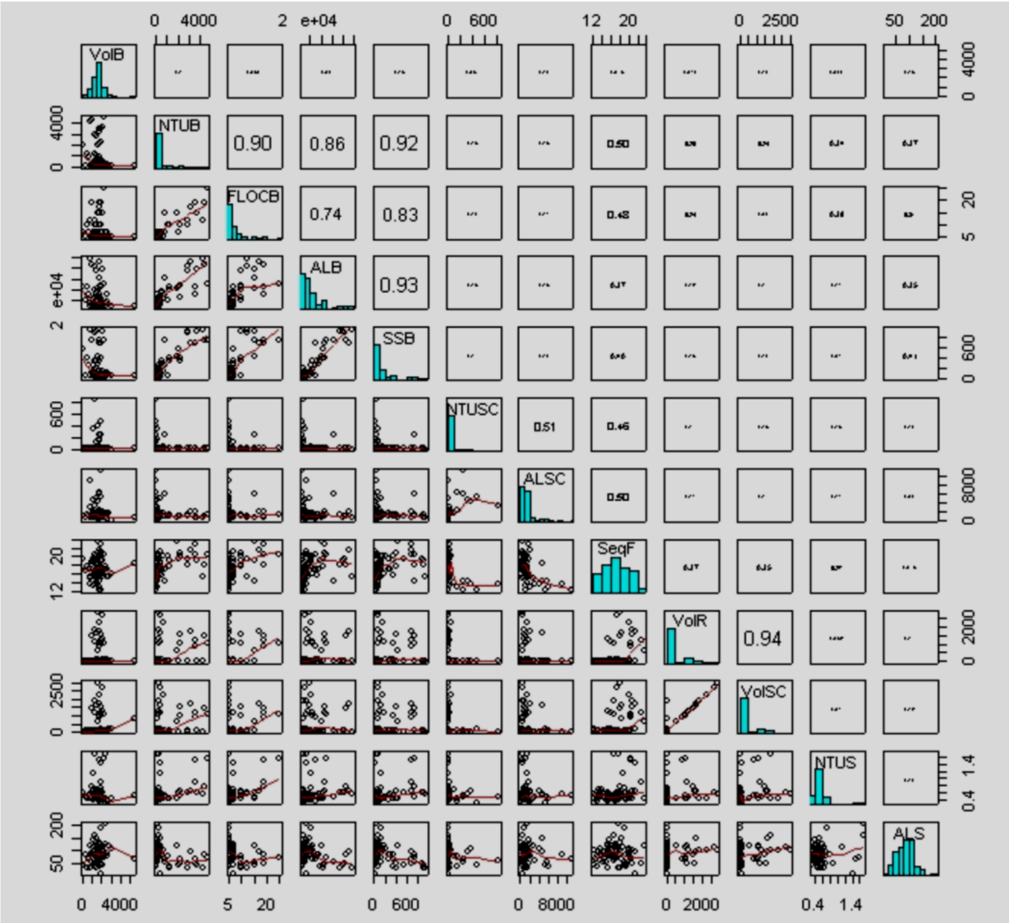

Figure 4: Multivariable correlation general process at 10 % of recirculation

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