ISBN: 978-628-96613-1-6. ISSN: 2414-6390. Digital Object Identifier: https://dx.doi.org/10.18687/LACCEI2025.1.1.1331

Proposal to reuse water from a conventional tailing in an area of low water potential in Peru

Fabio Mazziotti, MBA, 0009-0009-6812-6068; Maribel Guzman, PhD., 0000-0002-7954-7679
Pontifical Catholic University of Peru, Peru
a20132087@pucp.pe, mguzman@pucp.edu.pe

Abstract– In recent years, technology has allowed mining processes to be developed with fewer environmental impacts. A great concern is related to the use of water in extractive processes. In this opportunity, an evaluation of the recovery of tailings water using thermoplastic filters is presented. For the study, a gold ore processing plant located in a region with a water deficit was chosen. The investment in the filtering system amounts to US$778,460. The filtering system allows the recovery of 103,680 m³/y of water, which could be used to develop other industrial activities in the study area. With the recovered water, previously treated, it would be possible to plant cotton, olive trees and ornamental flowers (roses).

Keywords-- Mine tailings, thermoplastic filters, water recovery.

I. Introduction

In recent years, the mining industry has been implementing various strategies to develop its operations in a sustainable manner [1,2]. In fact, the possibility of using mining tailings as raw material for the construction industry has been evaluated [3-5], while in other mining operations efforts are being made to reduce water demand by reusing and recycling water within the various stages of the mining operation [6-8]. Normally, the effluents generated in various mining stages (drilling, concentration plant, tailings area, etc.) are reused [9-11]. However, the issue of recovering water contained in mining tailings to reuse it in other productive activities in areas close to mining exploration has been little explored. To recover water from conventional tailings, mining companies are opting for dry stacking tailings deposits technology. This technology allows tailings to be disposed of in a reduced space, since the recovered water reduces the volume needed to place the drained tailings [12-18].

To recover water from tailings, it is necessary to take into consideration the type of tailings with which one is going to work. Among the types of tailings, we have:

- Conventional tailings (30-55% of solids in suspension)
- Thickened tailings (50%-70% solids in suspension)
- Tailings in paste (70%-85% solids in suspension)
- Filtered tailings (>85% solids in suspension)

There are different water recovery systems for mining tailings, such as tanks and filters, for different applications. To take advantage of the water resource, the recovered water is generally recirculated to the beneficiation plant for reuse during the mineral extraction process. Below we will mention the types of filters used to recover water from tailings:

- Conventional filters (vacuum filtration with disc filters, belt filters, or press filters)
- Modern high-performance vacuum disc filters
- Thermoplastic filters

Conventional filtration uses a system supplied by vacuum pumps to extract liquid from the tailings. The three main parts of the system are drum, disc and horizontal belt filters. Among the advantages of the conventional filtering process, we can mention that there is a constant reduction in costs because the manufacture of the filters and the feeding of the tailings is a continuous process. However, its main disadvantage is that the production speed depends on the filtration time, a cycle takes from 8 to 15 minutes depending on the pressure supplied to the filter [19-22].

Technological advances have improved filter design details, resulting in modern high-performance vacuum disc filters. This has improved filtering capacity, performance, operational safety and reliability, and maintenance and operating costs.

On the other hand, in recent years, thermoplastic filters have emerged as an interesting application alternative. In fact, these types of filters have filtered more than 10 million tons since 2011 and have been successfully installed in several projects throughout America using outstanding and efficient techniques designed to meet the needs of different clients [23]. These filters are widely used in the metal processing industry. These include gold, copper, and specific results in the treatment of iron and polymetallic concentrates.

In Peru, mining operations are mainly carried out in the high Andean zone, between 3000 and 5500 meters above sea level. Some other units are developed on the coast of Peru; and depending on the location, there may be limited access to water. On the other hand, in Peru, the recovery of water from tailings would improve the relationship between the mining company and the communities, given that 53.4% of the social conflicts that arose in the country were due to water disputes; and of these, 60.2% are related to the mining industry [24]. In this sense, a limited demand for water by mining companies would not only allow the development of operations in a sustainable manner but would also allow the development of other productive activities [25].

II. Helpful Hints

A. *Case study*

To assess the feasibility of recovering water from mine tailings, a beneficiation plant located in the district of Chala, province of Caravelí, department of Arequipa was chosen [26] (Fig. 1).

Fig. 1 Location of gold and silver ore beneficiation plant (case study).

The beneficiation plant processes around 300 TMS/d with an average grade of 0.6 Oz/Tc of Au and 6 Oz/Tc of Ag. The beneficiation plant includes crushing, grinding, cyanidation, recovery by Merrill Crowe with carbon in leach (CIL) and carbon in pulp (CIP), desorption, electrowinning, smelting and disposal of tailings and waste [27]. Once the metallurgical process is completed, a tailing with the following characteristics is obtained:

- Tailing: Au-CN
- Target production: 300 t/d
- Source: Desorption plant/Cyanidation circuit
- Percentage of final water: 60%
- Destination: Tailing's dam
- % Solids: 40%
- Additive: None
- Temperature: 17ºC

B. Water demand and consumption in the area

An estimated 50 families were found in the farming community in the Chala district [26]. In 2017, the number of inhabitants in the district was estimated at 9,240 with an average water consumption of 8.07 m^3/year, when the minimum recommended water consumption is 36.5 m^3/year. The Chala district has 20 conventional tailings deposits and a river with an average flow of 0.7 m^3/s.

Table I shows the total number of men and women registered from 2018 to 2022 in the province of Caravelí and 13 constituent districts. There is an increase of 1494 people between 2018 and 2022 in the district of Chala, which represents a growth of 13.8% in the next five years [28].

TABLE I
TOTAL POPULATION IN DISTRICTS OF THE PROVINCE OF CARAVELÍ

District	2018	2019	2020	2021	2022
Caraveli	4157	4198	4227	4284	4332
Acari	4976	5081	5172	5283	5381
Atico	5641	5809	5962	6127	6271
Atiquipa	511	493	475	466	455
Bella Union	3147	3065	2978	2935	2895
Cahuacho	646	628	609	599	591
Chala	9338	9862	10368	10605	10832
Chaparra	3653	3639	3613	3567	3516
Huanuhuanu	3080	3144	3199	3268	3327
Jaqui	1592	1585	1576	1581	1585
Lomas	1544	1548	1580	1603	1625
Quicacha	1899	1903	1902	1905	1906
Yauca	1976	2006	2029	2060	2087
Total	**42127**	**42961**	**43690**	**44283**	**44803**

The extension of the district and the number of inhabitants in 2022 are:

- Inhabitants (2022): 10832
- Extension: 278.38 Km^2
- Average water consumption: 8.07 m^3/year (22.1 liters/day)
- Number of mineral processing plants: 12
- Number of tailings deposits: 20 (12 operational + 8 closed)

Obtaining a population density of 38.9 people/Km^2. Conventional tailings contain between 30% and 40% liquids. The 12 plants located in the Chala district use conventional systems (August 2020). The minimum recommended water consumption is 36.5 m^3/year [29].

C. Population directly involved with mining in the province of Caravelí

Table II shows that of the districts of the Caravelí province with populations involved in mining, Chala is in 4th position with 503 participants, after Bella Unión with 1,291 people involved, Cháparra with 1,150 and Huanuhuanu with 1,019.

TABLE II
POPULATION DIRECTLY INVOLVED IN MINING [30]

District	Population employed in mining
Bella Union	1291 (30.5 %)
Chaparra	1150 (27.2%)
Huanuhuanu	1019 (24.1 %)
Chala	503 (11.9 %)
Acari	212 (5.0 %)
Jaqui	46 (1.1 %)
Yauca	8 (0.2 %)
Total	**4229**

1) Communities in the provinces of the department of Arequipa

The total number of recognized and titled communities in the provinces of the department of Arequipa is shown in Table

III. The province of Caravelí has 100% recognized peasant communities.

TABLE III
NUMBER OF RECOGNIZED PEASANT COMMUNITIES

Province	Districts	Total communities	Recognized and titled	Titled extension (ha)
Arequipa	29	15	15	323,677.67
Caravelí	13	9	9	148,991.99
Castilla	14	17	17	348,405.66
Caylloma	20	22	17	287,284.79
Condesuyos	8	18	17	250,975.62
La Union	1	23	20	56,438.81
Total	**85**	**104**	**95**	**1,415,774.54**

The number of families from the titled peasant communities in the department of Arequipa until 2009 is presented in Table IV. The peasant community of Chala Viejo, in the district of Chala, is made up of 50 families.

TABLE IV
FAMILIES BY PEASANT COMMUNITY IN THE PROVINCE OF CARAVELÍ

Province	Districts	Families
Otapara	Acari	135
Atiquipa, Jaqui and Yauca	Atiquipa	90
Chala Viejo	Chala	50
Huanuhuanu	Huanuhuanu	150
Total		**425**

2) *Direct area of influence of the mining company of the case study*

The Chala Viejo peasant community is located within the area of direct influence in a radius of 13 km, as is the district of Chala in a radius of 8 km, as shown in Fig. 2.

Fig. 2 Location of the benefit plant of the case study and the Chala Viejo peasant community [31].

3) *Natural water resources in the Chala district*

The natural system of the area is made up of 4 main basins in the region: Acarí, Yauca, Chala and Cháparra whose river characteristics are detailed in Table V [32]. Groundwater from the aquifers of the Acari and Yauca valleys are also used. There are 461 classified wells, 409 are in Acari and 52 in Yauca with a total exploited volume of 2,408 Hm^3.

TABLE V
WATER FLOW IN CHÁPARRA-ACARI

River	Distance (Km)	Flow rate (m^2/s)
Acará	194.7	17.5
Yauca	172.2	14.3
Cháparra	89.6	1.1
Chala	73.2	0.7

III. RESULTS

A. *Choice of filtering equipment.*

The operational capacity parameter for Au tailings is taken as a general standard for filtered products. In this case, the thermoplastic filters have a capacity to process tailings of 180 $kg/m^2.h$ [33]. Table VI describes the operating characteristics of 04 models of thermoplastic filters as the effective filtering area of each disc (m^2), the filter units, the number of ceramic discs per filter unit, which is constant, the total number of discs per equipment model, the total effective filtering area (m^2) and the hourly productive capacity (t/h).

TABLE VI
TECHNICAL AND PRODUCTION CHARACTERISTICS OF THERMOPLASTIC FILTERS [33].

Model	Disk filter area (m^2)	Filter Units	Ceramic Disks	Total disks	Total area(m^2)	Capacity (t/h)
YH-1	1	1	12	12	12	2.16
YH-4	2	2	12	24	48	8.64
YH-6	2	3	12	36	72	12.96
YH-8	2	4	12	48	96	17.28

The filtering equipment is sized according to the productive capacity of the processing plant. In the case of the processing plant in the case study, 2 units of model YH-4 thermoplastic filters are suggested with a joint hourly capacity of 17.28 (t/h) to satisfy the production of 15.0 (t/h).

The processing plant in the case study has a consumption of 600 m^3 daily and 216,000 m^3 annually, which represents an estimated 12.2% of the total annual consumption of processing plants (1,771,200 m^3).

B. *Estimation of annual water recovery in Chala.*

It has been determined that the difference between solids in pulp between a conventional tailing and a filtered tailings ranges between 44% and 48%. The difference in water content in pulp is 48% for a tailing filtered at a target value of 12% moisture by weight (Table VII).

TABLE VII
DIFFERENCE BETWEEN THE PERCENTAGE OF WATER IN PULP BETWEEN A CONVENTIONAL TAILINGS AND A FILTERED TAILINGS [34]

	% solids in pulp	% water in pulp
Conventional tailings	40%	60%
Leaked tailings	84% -88%	12%

The mineral processing plant of the case study processes an average of 300 t/d and 109,500 t/y for a perfect year, consuming 216,000 m^3 of water annually. The theoretical volume of water to be saved by having filtered tailings, with an average reduction of 48% is:

- 300 Tons of tailings processed daily (t/d)
- 109,500 tons of tailings processed annually (dt/y)
- 103,680 Theoretical volume of recovered water (m^3/y)

A recovery of 48% of water consumption in the Chala plants is estimated at a total of 850,175 m^3/y, while the district's consumption is only 74,566 m^3/y.

Local consumption is estimated in the rural community of Chala Viejo considering 50 families with an average of 4 members per family and an estimated consumption around 8.07 m^3 [26,28]. The estimate of local water consumption for the town of Chala Viejo and the percentage of consumption in Chala Viejo over the theoretical volume of water recovered in the mineral processing plant of the case study is less than 5% as described below:

- Estimated annual consumption of Chala Viejo: 1600 m^3
- Consumption in Chala Viejo / Theoretical volume of water recovered in the mineral processing plant of the case study (m^3/y): 2%

The estimated total annual consumption for all plants in the Chala district is 1,771,200 m^3/y and the theoretical volume of water to be recovered by providing filtered tailings with humidity of 12% would be 850,176 m^3/y.

On the other hand, the annual water consumption in the district of Chala amounts to 74,566 m^3/y, estimated according to the number of inhabitants of the district and their average consumption. The ratio between consumption in Chala and the theoretical volume of water recovered in the Chala plants (m^3/y) is less than 8.8%.

C. *Decrease in tailings volume and water demand*

Among the environmental aspects to consider, one of the most important is the reduction in tailings volumes that must be disposed of safely, to avoid spills, generation of fugitive dust and acid mine drainage, among others. As these are tailings with water contents of only 12%, the disposal area is reduced to a quarter as shown in Table VIII [34].

TABLE VIII
DIFFERENCE BETWEEN THE PERCENTAGE OF WATER IN PULP BETWEEN A CONVENTIONAL TAILINGS AND A FILTERED TAILINGS [34].

item	Conventional tailings	Leaked tailings
Tonnage (T)	300	300
Disposition area (m^2)	20,000	5,000
Underflow density (%)	40	84 - 88

On the other hand, if we calculate the volume of tailings that is discharged to the tailings pond and considering an average density of 1.3 g/l and an operating time of 14 months of production with a footprint of 20,000 m^2, we would be talking about a volume of 94,030 m^3 of tailings that we would need to dispose of safely per year.

Fig. 3 shows a theoretical comparison between the volumes required to deposit tailings of the three types: conventional, filtered and filtered flattened with a compactor. A flattened filtered tailing requires half the space to be disposed of than a conventional tailing. The natural swelling factor of 12% remaining humidity is disregarded [27,34].

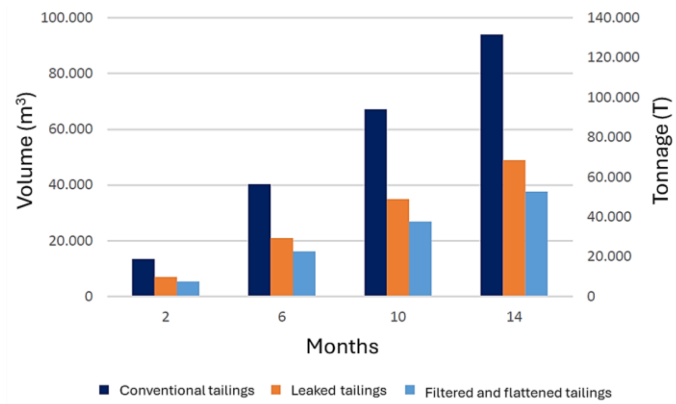

Fig. 3 Estimated volume required over 14 months of production for a conventional tailing with 40% solids content compared to the volume provision for a filtered tailing with 88% solids content [31].

The water recovered from the tailings prior to disposal could be recirculated to the mineral processing plant circuit, Irrigation of dry areas and revegetation or used in another economic activity that benefits nearby communities. We will carry out a roughly feasibility study of the last scenario.

D. *Development of secondary economic activities*

By doing prior research, three agricultural products were chosen that require little water and that can be placed in the national and international market: the olive tree, the cotton and the roses. For this analysis we take as a basis the volume of recovered water of 103,680 m^3/y (284 m^3/d) obtained after the filtration process. With this volume of water, an approximate estimate of the possible hectares to be revegetated can be made.

It is important to mention that before using the recovered water, it must be treated to eliminate or recover residual cyanide [35]. There are several methods for degrading CN^- present in aqueous solutions. In this case, we will choose the destruction of CN with hydrogen peroxide (equation 1).

$$NaCN_{(aq)} + H_2O_{2(aq)} \rightarrow NaOCN_{(aq)} + H_2O_{(l)} \quad \ldots(1)$$

According to equation 1, it is observed that for each mole of NaCN 1 mole of H_2O_2 is required. The estimated costs of cyanide destruction using this alternative are presented in Table IX.

TABLE IX

ESTIMATED INVESTMENT IN CYANIDE DESTRUCTION

Volume of recovered water (m^3/y)	CN^- concentration in recovered water (mg/L)	CN^- content in recovered water (g)
103,680	50	5184
Amount of H_2O_2 needed to destroy CN (kg)*f	Price of H_2O_2 (USD/Kg)	Total required (USD)
3957.90	2.32	9182.32

f = Safety factor (10%)

For the cultivation of any plant, it is necessary to consider:

- number of days watered (d)
- reference evapotranspiration (ETo)
- volume of water per plant (G)
- crop coefficient (K_c)
- irrigation efficiency (E_f)
- horizontal spacing between plants (hs)
- lateral spacing (ls)

Then the volume of water needed can be calculated using the following equation [36]:

$$G = \frac{ET_O . K_c}{E_f . d} . hs. sl \quad ...(2)$$

1) The olive tree

The cultivation of the olive tree is the most important in the province of Caravelí, Arequipa region. This region has an area of 2,894 hectares and an average annual production of 13,086 tons of olives [37].

Taking equation (2) as a reference, 0.25 m^3/plant per day would be needed to grow the olive tree [38]:

$$G = \frac{9\ mm/d\ x\ 0.5}{0.9\ x\ d} x\ 10\ m\ x\ 5m = 0.25m^3/plant.day$$

Theoretically, with 284 m^3/d, 1,136 olive trees would be irrigated, equivalent to 5.68 hectares, each tree occupying 50 m^2 (10m x 5m) and 200 trees per hectare. A revegetation of 2,073 hectares per year is estimated [31].

2) The Cotton

Cotton is also found within Caravelí's productive specialties [38]:

$$G = \frac{7\ mm/d\ x\ 1.2}{0.9\ x\ d} x\ 0.8\ m\ x\ 1.0\ m = 0.075m^3/plant.day$$

In this case, theoretically with 284 m^3/d, 3,787 cotton plants would be irrigated, equivalent to 0.3 hectares, each plant occupying 0.8 m^2 (0.8m x 1m) and 12,500 plants per hectare. A revegetation of 108 hectares per year is estimated [31].

3) The roses.

A final hypothetical case is also estimated to present the vegetation capacity for an ornamental crop, in this case the Rose, a crop which could generate commerce in the study area [39]:

$$G = \frac{10\ mm/d\ x\ 1.65}{0.9\ x\ d} x\ 0.6\ m\ x\ 1\ m = 0.11m^3/plant.day$$

Finally, for the ornamental rose with 284 m^3/d, 2,581 roses would be irrigated, equivalent to 0.155 hectares, each plant occupying 0.6 m^2 (0.6m x 1m) and 16,670 plants per hectare. A revegetation of 56.5 hectares per year is estimated [31].

Tables X and XI present a summary of the three types of crops considered in the possible revegetated areas. Income is considered based on the minimum and maximum yield of each crop and a 2024 reference price. The olive tree would have the highest income potential considering that it is the main commercial crop in the study area. However, it is necessary to mention that each crop requires special treatments and involves a diverse investment environment, depending on the cultivation and harvest time.

TABLE X

SUMMARY OF YIELD AND ESTIMATED THEORETICAL VALUE OF INCOME OF OLIVE AND COTTON

Product	Ha	Tn/Ha	Production (Tn)	Price (USD)[c)]	Income (USD)
Olive	2073	10[a)]	20,730[a)]	1.6	33,168,000
		12[b)]	24,876[b)]		39,801,600
Cotton	108	0.66[a)]	71.28[a)]	2.02	143,985.60
		1.33[b)]	143.64[b)]		290,152.80

[a)]minimum production; [b)]maximum production; [c)]price per kilo.

TABLE XI

SUMMARY OF YIELD AND ESTIMATED THEORETICAL VALUE OF INCOME OF ROSES

Ha	Plants/Ha	Dozen per plant	Dozen per Ha	Price (USD)	Income (USD)
56.5	16,670	2.5[a)]	2,354,637.50	2.63[c)]	6,192,696.63
		5.0[b)]	4,709,275.00		12,385,393.25
		2.5[a)]	2,354,637.50	1.32[d)]	3,108,121.50
		5.0[b)]	4,709,275.00		6,216,243.00
		2.5[a)]	2,354,637.50	0.53[e)]	1,247,957.88
		5.0[b)]	4,709,275.00		2,495,915.76

[a)]minimum production; [b)]maximum production; [c)]price per dozen top quality; [e)]price per dozen second quality; [f)]price per dozen third quality [40].

Considering the investment required to destroy cyanide in reclaimed water (9182.32 USD), we can affirm that the production of olives, roses, and cotton is feasible due to their positive income balance.

E. Thermoplastic filter system implementation cost estimate

The implementation of a system with thermoplastic filters starts with the filtering equipment. The Capex contribution for the equipment is US$ 426,052, which includes 2 filtering units, insurance and installation.

The filtration capacity is stimulated with higher density sludge, so a 40 x 12-foot thickening tank is chosen. The flow thickened to 55% suspended solids will be filtered from your flocculation. An estimated expense of US$ 154,202 includes installation, supports and auxiliary mechanisms. A nitric acid tank is also included for the care and cleaning of the machines [34]. An estimate of the total investment needed is summarized in Table XII.

TABLE XII
INVESTMENT CAPEX FOR THERMOPLASTIC FILTER SYSTEM

Description	Investment (USD)
Detail engineering	38,940
EIA	38,940
Site preparation	53,737
Filtering systems	426,052
Thickener tank	154,202
Nitric acid tank	5,192
Belt system	61,395
Total Capex (USD)	**778,459**

In addition to the investment amount, it is necessary to calculate its operating and maintenance expenses. The Opex of the filtering systems varies for the first year considering that the maintenance and service for the filtering equipment for the first 12 months are granted as a guarantee for their purchase, calculating at US$ 15,947.37/month and 191,370.80/year [34]. A total estimate of the necessary requirements is summarized in Table XIII.

TABLE XIII
OPEX ESTIMATION OF THERMOPLASTIC FILTRATION SYSTEM

Description	Monthly cost (USD)
Maintenance of Filtering Machines	5,138.17
Energy consumption	1,135.15
Supplier maintenance	1,384.17
Hauling and compaction	11,600.00
flocculant	958.50
Supervision	869.75
Total Opex (USD)	**21,085.74**

IV. CONCLUSIONS

With the evaluation carried out we can affirm that it is possible to use thermoplastic filters to recover tailings water from a mining process.

The economic evaluation shows that, in the span of 6 years, the implementation of the tailings filtering system with thermoplastic filters is viable given that the CAPEX is US$ 778,460.

It was determined that the system with thermoplastic filters allows a recovery of approximately 48% of water from a conventional tailing, which represents a recovery of 103,680 m^3/year.

It was determined that the volume of recovered water could be used to revegetate 56.7 ha with rose bushes, 108 ha with cotton plants or 2073 ha with olive trees. It would mean average annual income of US$ 5,274,388; US$ 217,069 and US$ 36,484,800 respectively. However, it will be necessary to carry out a detailed economic analysis to evaluate costs related to investment and operation issues.

ACKNOWLEDGMENT

This work has been supported by Dynacor Gold Mines, who kindly provided the data.

REFERENCES

[1] G. Li, Z. Hu, P. Li, D. Yuan, Z. Feng, W. Wang, and Y. Fu, "Innovation for sustainable mining: Integrated planning of underground coal mining and mine reclamation," *J. Clean. Prod.*, vol. 351, no. 131522, pp. 391–408, June 2022.

[2] A. Ivic, N. M. Saviolidis, and L. Johannsdottir, "Drivers of sustainability practices and contributions to sustainable development evident in sustainability reports of European mining companies," *Discov Sustain*. vol 2, no. 17, pp. 1-20, March 2021.

[3] R. Liza, P. Pereyra, J. Rau, M. Guzman, L. Sajo-Bohus, and D. Palacios, "Assessment of Natural Radioactivity and Radon Exhalation in Peruvian Gold Mine Tailings to Produce a Geopolymer Cement," *Atmosphere*, vol. 14, no. 3, pp. 588-599, March 2023.

[4] J. A. Rau, P. E. Pereyra, M. Guzman, and A. Ruiz, "Recycling of mining tailings into construction materials such as geopolymer cement," pp. 1-9, July 2023 [*LACCEI 21st LACCEI International Multi-Conference for Engineering, Education, and Technology, Argentina*].

[5] C. Toledo, M. Guzman, J.A. Rau, P. Pereyra, and Ruiz A, "Geopolymerization of mining tailings as an alternative for its use in the construction industry," pp. 1-8, February 2024 [*SME, MINEXCHANGE 2024 SME Annual Conference & Expo, United States of America*].

[6] P. Kinnunen, R. Obenaus-Emler, J. Raatikainen, S. Guignot, J. Guinera, A. Ciroth, and K. Heiskanen, "Review of closed water loops with ore sorting and tailings valorisation for a more sustainable mining industry," *J. Clean. Prod.*, vol. 10, no. 123237, pp. 1-11, August 2020.

[7] K. D. Miller, M. J. Bentley, J. M. Ryan, K.G. Linden, C. Larison, B. A. Kienzle, L. E. Katz, A. M. Wilson, J. T. Cox, P. Kurup, K. M. Van Allsburg, J. McCall, J. E. Macknick, M. S. Talmadge, A. Miara, K. A. Sitterley, A. Evans, K. Thirumaran, M. Malhotra, S. Garcia Gonzalez, J. R. Stokes-Draut, and S. Chellam, "Mine Water Use, Treatment, and Reuse in the United States: A Look at Current Industry Practices and Select Case Studies," *ACS EST Engg.*, vol. 2, no. 3, pp. 391–408, October 2021.

[8] S. C. Franca, L. S. Andrade, P. E. V. Loayza, and B. C. Trampus, "Water in Mining – Challenges for Reuse," pp. 445-452, June 2017 [*IMWA 13th International Mine Water Association Congress: Mine Water & Circular Economy – A Green Congress, Finland*]

[9] C. Cacciuttolo, and F. Valenzuela, "Efficient Use of Water in Tailings Management: New Technologies and Environmental Strategies for the Future of Mining," *Water*, vol. 14, no. 1741, pp. 1-16, May 2022.

[10] N. Araya, Y. Ramirez, L. A. Cisternas, and A. Kraslawski, "Use of real options to enhance water-energy nexus in mine tailings management," *Applied Energy*, vol. 303, no. 117626, pp. 1-15, August 2021.

[11] B. Camara, and S. C. Alves, "Rheology applied to the environmental management of mineral tailings: focus on safer disposal and water reuse," *Int. Eng. J.*, vol. 72, no. 2, pp. 301-306, June 2019.

[12] E. Furnell, K. Bilaniuk, M. Goldbaum, M. Shoaib, O. Wani, X. Tian, Z. Chen, D. Boucher, and E. R. Bobicki, "Dewatered and Stacked Mine Tailings: A Review," *ACS ES&T Engineering*, vol. 2, no. 5, pp. 728-745, April 2022.

[13] M. P. Davies, and S. Rice "An alternative to conventional tailing management – "dry stack" filtered tailings," in Tailings and Mine Waste 2001, A. A. Balkema, Ed. Florida: CRC Press, 2022, pp. 484 – 494.

[14] P. Newman, M. Bruton, J. Burgos, and J. Purrigton, "Innovations in Tailings Management - Hydraulic "Dry" Stacking," pp. 1129-1140, November 2022 [TMW2022: 26th Tailings & Mine Waste Conference 2022, United States of America]

[15] A.L.C. Rissoli, G.S. Pereira, A.J.C. Mendes, H.C.S. Filho, J.V. de A. Carvalho, A. C. Wagner, J.P. de S. Silva, and N.C. Consoli, “Dry Stacking of Filtered Iron Ore Tailings: Comparing On-Field Performance of Two Drying Methods,” *Geotech Geol Eng*., vol. 42, pp. 2937–2948, November 2023.

[16] D. Dimitriadis, E. Zachareas, and V. Gazea, “Upgrading of a Tailings Management Facility for the Disposal of Dry Stack Tailings,” *Mater. Proc.*, vol. 5, no. 132, pp. 1-11, June 2022.

[17] J.L. Lara, E.U. Pornillos, and H.E. Muñoz, 2013, “Geotechnical-geochemical and operational considerations for the application of dry stacking tailings deposits – state-of-the-art,” pp. 249-260, June 2013 [*Paste 2013: 16th International Seminar on Paste and Thickened Tailings*, Australian Centre for Geomechanics, Perth, Australia]

[18] C.S. Hogg, 2010, “Filtered tailings in Western Australian iron ore projects — comparison of filtered tailings with other tailings disposal methods,” pp. 463-472, September 2010 [*Mine Waste 2010: First International Seminar on the Reduction of Risk in the Management of Tailings and Mine Waste*, Australian Centre for Geomechanics, Perth, Australia]

[19] A.H. Watson, P.G. Corser, E.E. Garces Pardo, T.E. Lopez, and J. Vandekeybus, “A comparison of alternative tailings disposal methods,” pp. 499-514, September 2010 [*Mine Waste 2010: First International Seminar on the Reduction of Risk in the Management of Tailings and Mine Waste*, Perth, Australia]

[20] A. Carneiro, and A.B. Fourie, “A conceptual cost comparison of alternative tailings disposal strategies in Western Australia,” pp. 439-454, April 2018 [Paste 2018: *21st International Seminar on Paste and Thickened Tailings*, Perth, Australia]

[21] G.I. McPhail, R. Ugaz, and F. Garcia, “Practical tailings slurry dewatering and tailings management strategies for small and medium mines,” pp. 235-243, May 2019 [Paste 2019: *22nd International Seminar on Paste and Thickened Tailings*, Cape Town, South Africa]

[22] J. Hanh, “Tailings dewatering with increased filtration rates and lowest filter cake moisture for filtered tailings stacking,” pp. 245-257, May 2019 [Paste 2019: *22nd International Seminar on Paste and Thickened Tailings*, Cape Town, South Africa]

[23] Mining Systems, CEC. https://cecminingsystems.com

[24] R. Mogrovejo, F. Alburqueque, and L. Zavala, “Conflictos sociales y recursos hídricos,” DP/APCSG, Lima, Peru, 2015.

[25] A. J. Gunson, B. Klein, M. Veiga, and S. Dunbar, “Reducing mine water requirements,” *J. Clean. Prod.*, vol. 21, no. 1, pp. 71-82, January 2012.

[26] Instituto Geológico, Minero y Metalúrgico, INGEMMET, https://portal.ingemmet.gob.pe/web/guest/presentacion

[27] L.M. Espinoza, “Estudio de investigación para la recuperación de oro y plata de los relaves de la planta veta dorada S.A.C.,” UNSA, Arequipa, Perú, 2017.

[28] INEI. (2018). Población estimada al 30 de junio, por años calendario y sexo según departamento, provincia y distrito, 2012 – 2015. En: Estimaciones y Proyecciones de Población.

[29] J. Soto, “Recuperación de agua mediante sistema de filtros termoplásticos y disposición de relaves en seco – beneficios ambientales y económicos. *Revista Minería*, vol.7, no. 490, pp. 59-67, July 2018

[30] IBC, “Sistema de información sobre comunidades campesinas del Perú,” in Directorio de comunidades campesinas del Perú, P. Tipula and S. Alvarado, Eds. Lima: Tarea Asociación Gráfica Educativa, 2016, pp. 81-87.

[31] F. Mazziotti, “Evaluación técnico-económica de la recuperación de agua de relave convencional mediante el uso de un sistema de filtrado y disposición de relave en seco,” PUCP, Lima, Peru

[32] Autoridad Nacional de Agua, ANA. https://www.ana.gob.pe/organizacion-funciones/organigrama/organigrama

[33] YH, YH Machinery Canadá Ltda. (2018). https://yhmmp.com/

[34] C. Stockman, J. Soto, and D. González, “Peruvian gold-cyanide tailings filtration – a detailed cost comparison,” pp. 1-14, June 2014 [Paste 2014: *17th International Seminar on Paste and Thickened Tailings*, Vancouver, Canada

[35] G.M. Ritcey, “Tailings management in gold plants,” Hydrometallurgy, vol. 78, no. 1-2, pp. 3–20, March 2005.

[36] M. Briceño, F. Álvarez, and U. Barahona, “Manual de Riego y Drenaje. Programa de Manejo Integrado de Plagas en América Central. Carrera de Ciencia y Producción Agropecuaria,” EAP, El Zamorano, Honduras, 2012.

[37] Ministerio de Desarrollo Agrario y Riego, MIDAGRI. https://siea.midagri.gob.pe/portal/

[38] R. G. Allen, L. S. Pereira, D. Raes, and M. Smith, “Evapotranspiración del cultivo Guías para la determinación de los requerimientos de agua de los cultivos – FAO,” Roma: FAO, 2006

[39] J. J. Arévalo, J. E. Vélez, and J. H. Camacho-Tamayo, “Uso eficiente del agua para el cultivo de rosa cv. Freedom bajo invernadero,” *Rev. Bras. Eng. Agric. Ambient.*, vol. 17, no. 8, pp. 811-817, August 2013.

[40] L. Huaman, “Costos de producción y el precio de las rosas en la asociación de floricultores “Sawasiray”, Cusco, 2020,” UJCM, Moquegua, Perú, 2021.