Technical, technological and environmental aspects of the management of technological waters in mines and concentrators owned by KGHM Polska Miedź S.A.

K Witecki and A Grotowski

KGHM Cuprum Ltd. Research and Development Center, Gen. W. Sikorskiego 2-8, 53-659 Wroclaw, Poland

E-mail: kwitecki@cuprum.wroc.pl

Abstract. Water and Tailing Management System (WTMS) plays a key role in mining and processing technological chain. In general, two separate but dependent systems can be separated: a network of technological waters and tailings. They constitute a system of connected vessels, a perfect example of which is the WTMS owned by KGHM Polska Miedź S.A. and managed by Hydro technical Department (O/ZH). The mining, technological and flotation water transport systems included in the system together with the accompanying facilities and installations cover the area of approx. 15 x 26 km. They combine 3 mines, 3 concentrators (ZWRs), Żelazny Most Tailing Management Facility (TMF) and the Głogów discharge station. This system makes it possible to conduct mining and processing operations by collecting water from mine workings (drainage), supplying concentrators and other installations (filling) with process water, flotation tailing management and discharge of excess water to the environment. The necessity of excess water discharge is associated with a positive balance of the system. This state results from the specific hydrogeological conditions and applied technological solutions, while providing the opportunity to work without the need to extract fresh water from the environment. Working in closed circuit, the technological water network fits in with the principle of the “circular economy”, while meeting the quality requirements of the water both for the sake of issued permits and the flotation process. The global trend in the management of flotation tailings is being observed towards deposition them in thickened form in order to increase the safety of TMF and the best sign in to the BAT requirements. Positive examples obtained in this field by KGHM were possible due to many years of research conducted not only in this direction but also on the reuse of flotation tailings.

1. Introduction

The production of basic metal concentrates - including copper concentrates - requires significant volumes of water to carry out grinding and flotation processes as well as to managing huge waste stream with a size practically equivalent to the tonnage of the processed ore [1]. Economic conditions force everybody to constantly increase the ore throughput, and this entails the need to build the necessary Water & (flotation) Tailing Management System (WTMS) or to adequately develop it [2]. WTMS must ensure safe storage of tailings generated during concentration process, retention of the necessary water volume and its continuous supply according to the needs of processing, as well as, periodic, environmentally safe discharge of water to the nearby watercourses or reservoirs.
Water management in individual mines can vary considerably, depending on specific hydrological, hydrogeological, technological and environmental conditions, wherein, the majority of mines with the negative water balance – in contrast to KGHM Polska Miedź S.A. -, bases on supplementing a technological water system with waters from reservoirs (seas, oceans, lakes) and watercourses [3-5]. This is a serious obstacle especially when conducting concentration processes in dry regions, e.g. Chile, Australia [6, 7], because it forces to carry out additional investments, including construction of water intakes, treatment stations, pumping stations and water transport networks, of a length often exceeding 100 km [3]. If the water balance is positive, i.e. the inflow of water from mine dewatering is greater than their consumption in concentration processes, then periodic discharge of excess water into environment is necessary [8]. In line with global trends, the aim of any water management system is to ensure that water once introduced into the system is used as long as possible, while maintaining their parameters on the required level, to establish both an efficient concentration process and safe water discharge [3, 4].

Process water circling in WTMS is a mix of water from the flotation taillings and concentrate dewatering processes, other various types of water entering the system and make-up water. Maintaining the required water parameters in the global mining industry is becoming more and more difficult due to the widespread use of closed water circuits and the need to supplement the system with low quality waters and/or return water with an increased content of dissolved and/or solids, which results in a continuous deterioration of technological water quality [9]. In critical cases, the quality of used waters is being improved by the addition of low-mineralization waters, obtained by usage, among others, desalination installations [10]. It should be noted, however, that in most cases, highly saline waters are successfully used for flotation [4, 11-13]. Conducting flotation in such conditions requires adjusting the technological parameters of the process to the properties of the concentrated ore and the chemical composition of the water used. Numerous literature reports shows that parameters such as, among others, pH, heavy metals and salt concentration affect the selectivity of the flotation process [14-16], and that the salinity improves the foaming properties of the solution [17-22].

The tasks of water & flotation tailing management systems and their technical solutions are closely related not only to the water balance and local conditions but also to the method of tailing deposition. In the most of cases taillings are deposited in the same form as they leave the last cells of flotation machines. However, flotation taillings are more and more subjected to dewatering before dumping them, in order to obtain the possibly dense slurry [23-26]. This second solution has become a standard wherever there is a shortage of natural waters with quality suitable for supplementing industrial water circuits [27-30]. In order to accelerate the sedimentation of solids, different types of thickeners are used - especially high-rate thickeners, hydrocyclones, and the settling process is usually supported by the addition of flocculants/coagulants [4, 29, 31]. For a long time an increase trend of dense taillings storage is observed in flotation taillings management. Different slurries are used: from simply thick, through paste-like slurry, on dry (almost) taillings ending. [28, 30-32]. This trend results both from the attachment of more and more attention to the safety of Tailing Management Facilities (TMF), as well as from growing amount of information on the failures of various TMFs in recent years [23, 33, 34], and is also caused by the increasingly wider introduction of circular economy principles [35-37].

Water and flotation tailing management in KGHM Polska Miedź S.A. is an example of a system using water exclusively from own resources, which consists of waters from mine drainage, waste water, water from refreshing cooling circuits and - above all - return waters from the concentration process. This is a typical system with a positive water balance, which requires periodic discharge of excess water to the environment. In the currently exploited Tailing Management Facility (Żelazny Most OUOW), taillings are stored in the form of a slurry discharged on so called tailing beaches. In the planned extension of the current TMF with the so-called The Southern Quarter, the dams will be constructed using the tailing segregation and thickening technology.
2. Water and Tailing Management system in KGHM Polska Miedź S.A.

Initially, in the currently exploited LGOM copper basin, the water balance was negative, which resulted mainly from inadequate in relation to the needs - inflow of water from mine drainage. Therefore, it was necessary to supply WTMS with water coming from the Odra River. The changes caused by the development of the extraction and the associated significant increase in the inflow of water caused that for a long time the water balance is positive and a periodic discharge of excess water is necessary. The Odra I water intake, located at the current discharging node, was finally excluded from use in the mid-1980s [38].

The detailed tasks of WTMS, including mines and concentrators of KGHM Polska Miedź S.A., are as follows:

- collection of mine water and treated rainwater-technological waters and treated sanitary sewage from all 3 mines and 3 concentrators and their safe retention in the Żelazny Most Tailing Management Facility,
- collection of flotation tailings from all 3 concentrators plants and their safe storage (disposal) at Żelazny Most TMF,
- continuous delivery of water to all 3 concentrators, with the quality required for the processing operations, in a quantity appropriate to the processing volume of a given plant,
- periodical discharge of excess waters from the WTMS to the Odra River, in accordance with the ruling water permit.

In WTMS, the management of various types of water is carried out and the waters are sometimes called - depending on the place of origin - in various ways. These are mainly mine water (underground), water introduced by Energetyka sp. z o.o. and mine-technological water. The meaning of the individual terms is explained below.

- **Underground water**, also called mine water, comes from draining of the underground part of the mine. They are captured at the bottom of the mine and using the system of pipelines, settlers and departmental and regional pumping stations are transported to the main dewatering pump station, from where they are pumped on the surface. The underground water intake and transport network is organized in such a way as to make maximum use of gravitational flow. After pumping on the surface, mine water is supplied to surface water transport and distribution systems.
- **Energetyka Ltd. waters** are a mixture of pre-treated rainwater and technological waters from shaft sites, sewage and water from refurbishing cooling systems. They are fed into water transport and distribution systems.
- **Process waters** (also known as industrial, mine-technological, mine-industrial waters), are a mixture of mine waters from individual mines, supernatant and infiltration waters from Żelazny Most TMF and used waters of Energetyka Ltd. All these waters are returned to concentrators plants, where they are used for the processing of copper ores.

There are other names for the technological waters coming from specific parts of the WTMS network.

- **Supernatant water** is a clear, free of suspension water, accumulating over settled down flotation tailings at Żelazny Most TMF. It is collected using the so-called overflow towers and returned to concentrators or discharged to the Odra River.
- **Return water.** This is the name used for this part of the supernatant water that is returned to a concentrator. It is the most important component of waters used for the flotation process.
- **Discharge water.** This is the name used for this part of overflow waters that are directed to the Odra River through the control and discharge node in Głogów. Due to the fact that more water comes from the mines than it is consumed in the concentration process) and lost as the humidity of stored waste, evaporation of water, infiltration and as a concentrate moisture), the excess water must be - and is - systematically discharged to the Odra river.
The WTMS is composed of the transport networks for mining and technological waters as well as flotation tailings with the accompanying facilities and installations, located in the area between Lubin and Głogów, with an surface area of approx. 15 x 26 km. This system is characterized by the following functionalities:

• underground transport of mine water to the surface - to the frame of the shaft,
• surface transport of mine water - from the shaft framework to the concentrators (ZWR),
• (hydro) transport of flotation tailings and technological waters from ZWRs to Żelazny Most TMF,
• transportation of technological waters from Żelazny Most TMF to individual ZWRs and/or to the discharge node,
• collection of water from the Gilów TMF,
• the discharge of excess technological waters to the Odra River,
• the discharge of excess technological waters to the Odra River,
• the discharge of excess technological waters to the Odra River in controlled way, in terms of quantity and quality.

The volume of water discharged to the Odra river depends on the current river flowrate and quality parameters of the river and discharge water and is calculated taking into account the amount of permissible pollution load that can be introduced to the river, while maintaining the parameters specified in the integrated permit.

Water can be discharged to the Odra river in two ways:

• Gravitational - without the use of pumping sets,
• Pressure - using pump sets.

A simplified scheme for the circulation of waters and tailings in WTMS is presented in Figure 1.

![Figure 1. Simplified flowsheet of Water and Tailings Management System (WTMS) of KGHM Polska Miedź S.A.](image)

As part of the WTMS operating at KGHM Polska Miedź S.A. two types of networks can be distinguished, basically differing in the type of medium flowing through, applied technical and technological solutions and tasks assigned to them. These are:
1) Technological waters network.
2) Hydro transport network of flotation tailings

2.1. Technological waters network
The hydro transportation network of water (also known as mine-industrial water), managed by Hydro technical Department (O/ZH), is the longest pipeline network used by KGHM Polska Miedź S.A. The tasks of the technological water network are:
- collection of waters from mines,
- collection of treated sanitary sewage and treated rainwater-industrial waters from ZG Lubin West and Rudna West,
- transport of technological waters to the discharge node in Głogów, with the necessary assistance from Żelazny Most TMF,
- receiving of the clarified return water from Żelazny Most TMF and its delivery to ZWR, in the required quantity and quality,
- collection of excess water from the Gilów TMF reservoir,
- transport of excess water from Żelazny Most TMF to the control and discharge node,
- in necessary cases, purification of the supernatant waters stored in the Żelazny Most TMF from the suspension in the treatment plant next to the facility.

The most important task of the technological water network is to supply the concentrators. In addition, one of the backfill plants is also fed.

The technological water pipeline network is predominantly autonomous in relation to the waste water transport network. Only on the section, concentrators - Żelazny Most TMF, process water is sent along with flotation tailings in the form of an aqueous slurry. The network consists of:
- pipelines for water intakes A, B (closed), D and E in Żelazny Most TMF,
- return water return pipes from water intakes A, B (inactive), D and E,
- Kalinówka and Tarnówek pumping stations,
- infiltration water reservoirs at above mentioned pumping stations,
- return water pressure pipelines,
- distribution station of technological and mine water,
- Polanka retention reservoir,
- treatment plant of water discharged to the Oder River,
- pipelines for discharging supernatant water to the Odra River.

Supernatant water, accumulated in the central reservoir of Żelazny Most TMF, is collected by siphons placed in towers of overflow intakes and pipelines arranged in the bottom of the reservoir, and is supplied to the pumping station (Tarnówek and Kalinówka). From here it is pumped back to the concentrators for flotation, and its excess is discharged to the Odra River, according to the conditions of the integrated permit granted.

The collection of supernatant waters from Żelazny Most TMF takes place by means of tower intakes, located in the reservoir. W-3 and W-6 overflow tower intakes are inactive, W-10 and W-11 intakes feed, respectively, A, B (inactive), D and E inflow lines, which are then connected to the technological water pipeline network. The inflow of supernatant overflow waters to the system is permanent.

The technological water pipeline network is diverse and includes sections of underground, ground, surface and overhead pipelines, made of steel, cast iron, polyethylene and polyester resins, with diameters from 400 to 1,400 mm, with a total length of approx. 150 km. The final element of the technological waters network is the control and discharge node in Głogów.

The pressures and flows sizes in individual pipelines depend on the current concentrators needs and fluctuate. The working pressure at the Tarnówek pumping station varies between 10-13 atm, and at small demand it drops below 11 atm. The Kalinówka pumping station runs between 11 and 14 atm. The pressure value decreases with distance, depending on the terrain. For example, the RW-4 pipeline supplying the Rudna concentrator, at the Tarnówek pumping station, has a working pressure of 12
atm, whereas at the concentrator the pressure drops to 2.7 atm. Flowrates occurring in pipelines supplying water to individual concentrators are:

- RW-4 pipeline from 90 to 120 m³/min,
- Lubin pipeline (RW-1) from 55 to 65 m³/min,
- Polkowice pipelines (R1, R2, R3 and R4) approx. 50 m³/min,
- Gilów pipelines (Gilów I and Gilów II) from 20 to 46 m³/min (periodically).

The key elements of the technological water transport network are presented in Figure 2 and they are:

- Tarnówek pumping station,
- Kalinówka pumping station,
- Gilów pumping station,
- technological water distribution station,
- Polanka retention reservoir,
- Świnino II chamber,
- Water discharge node.

2.2. **Hydro transport network of flotation tailings**

The hydro transport network of flotation tailings is also a part of the technological water transport network, because along with the flotation tailings from the concentrators, mine and process waters are also transported in the same pipeline to Żelazny Most TMF. Thanks to this - after clarification - it becomes possible to reuse them in the concentration processes and/or discharge them to the Odra River, according to current needs. For this reason, the hydro transport network of flotation tailings is also an important component of the WTMS, in which it performs the following tasks:

- transport of flotation tailings from individual ZWRs to Żelazny Most TMF,
- transport of mine water from individual ZWRs to Żelazny Most TMF (together with waste slurry).

Within the Żelazny Most TMF network itself provides also:

- selective discharge of coarse tailings to the beach near the embankment crown. This part of tailings is designated for dam construction,
- selective discharge of fine-grained tailings into the canopy of TMF to seal the bottom of the basin,
- discharge of all tailings into the Żelazny Most TMF canopy - only during the period of negative temperatures.

Flotation tailings from concentrators (Regions: Lubin, Polkowice, and Rudna) are supplied in the form of a hydrated mixture to Żelazny Most TMF with a network of large-diameter main pipelines. Then, through a network of distribution and discharge pipelines, the waste slurry is directed to the selected parts of beaches, so-called sections, where discharging is carried out.
Figure 2. Horizontal projection of the Water Management System of KGHM Polska Miedź S.A.

The general principle of tailing depositing in TMF is ring discharging - around the whole TMF circuit, whereby sandstone type tailings (Lubin and Rudna concentrators) are directed to the drainage slope of the dams, whereas the clay-carbonate tailings (Polkowice concentrator) are directed into the canopy of the facility through pipelines located on so-called piers (dams). In addition to the pillars for the discharge of Polkowice tailings, there are also piers for other tailings, but they are intended only for winter operation, because during periods of negative temperatures discharging tailings into beaches cannot be performed. In the winter period tailings are directed to the deepest regions of the water reservoir. Supernatant water, after sedimentation of tailings, is captured by overflow tower and drained from the facility.

The hydro transport network of flotation tailings includes (Figure 3):
- first-stage flotation tailings pumping stations at:
  - Lubin concentrator,
- Polkowice concentrator
- Rudna concentrator, A side,
- Rudna concentrator, B side,
  - discharge pipelines of tailings from the above pumping station,
  - LG and RG tailings distribution stations with PG and RG chambers,
  - tailing pipelines from the distribution station to the boundaries of TMF,
  - pumping stations,
  - pipelines distributing tailings around the TMF dams,
  - discharging pipelines on the beaches.

The network of tailings transport pipelines consists of overhead pipelines laid in earthwork and excavations, made of steel, reinforced concrete and plastic pipes (HDPE), diameters from 500 to 1,200 mm. The pipeline network is run in a strip of land up to 20 m wide and with a total length of approx. 100 km. In the case of renovation and maintenance works, the pipelines are emptied into dedicated settling tanks, located at the foot of the Żelazny Most TMF barrage.

Due to the systematically progressing wear of pipelines, they are cyclically rotated, as well as systematically exchanged and modernized. With currently modernized slurry pipeline networks, steel and reinforced concrete pipes are exchanged for plastic pipes. Plastic pipelines are characterized by very high abrasion resistance and lack of corrosion, while their unfavorable feature is lower resistance to high pressures.
Figure 3. Horizontal projection of the Tailings Management System (TMS) of KGHM Polska Miedź S.A.
3. Environmental aspects of the WTMS

Many global studies, as well as water management protocols (Water Stewardship Protocols) define guidelines for sustainable water management in a given region [39]. The mentioned studies indicate the necessity of rational use of water by limiting the use of fresh water and more efficient recycling of process waters, while ensuring their appropriate parameters. This can be achieved by using such water management technologies that meet the following requirements:

- all potential water sources are taken into account already at the stage of planning the water needs of a plant,
- technology ensures the use of available waters according to their nature (quality), and the use of high quality water should take place only in the necessary cases or when another source of water is unavailable, while ensuring the least possible side effects,
- water introduced into the water system is used to the maximum extent, especially in areas with a significant water shortage, to minimize the uptake of water from the environment,
- surplus water, in or outside the plant, are used in an optimal way to maximize efficiency and reduce environmental impact.

Thanks to a significant increase in environmental awareness, the European Union has introduced the Integrated Pollution Prevention and Control (IPPC) Directive, which imposes the Best Available Technology (BAT) standard, which allows enforcement of compliance with the emission limits imposed by industrial plants. In the scope of the best available technologies for water and waste management in mining, the European Commission in its recommendations defines the desired directions of actions [40]. The most important of them, already implemented by KGHM Polska Miedź S.A., include the reuse of technological waters, the use of sedimentation tanks for the separation of fines and the removal of suspended solids and metals from waters discharged to the environment.

The major accidents of traditional TMFs in the recent years have clearly indicated the technologies for storing thickened and dry waste as increasing the safety of the facility, due to the limitation or complete elimination of the main factor of potential failure which is a water reservoir located inside of TMF [42]. In the case of using the technology of thickened tailings in e.g. the Southern Quarter [41], in addition to the increased safety of local residents, the degree of infiltration of saline water into the reservoir bed will be also reduced, which had a measurable impact on the environmental impact of the facility [43].

The "circular economy" principle introduced in the recent years requires the possibly highest usage (recovery) of waste products [44]. In the case of waters used in flotation process, virtually every concentrator in the world - although to varying degrees - fulfills this principle. Similarly, the KGHM Polska Miedź S.A., where the water management takes place through WTMS, guarantees repeated use of each type of water introduced into this system. On the other hand - as the overview of global solutions shows - meeting the requirements of a circular economy with respect to flotation tailings is very far from satisfactory because cases of a significant use of flotation tailings practically does not exist, and if they appear, are caused by very specific factors. In the case of flotation tailings generated by KGHM Polska Miedź S.A. the situation is slightly better because they are used to construct TMF embankments, to seal the water reservoir canopy and to neutralize the waste sulfuric acid [1].

Application of such methods for tailing utilization (recovery) became possible due to the effects of many years of research conducted by KGHM Polska Miedź S.A. focusing on reuse of flotation tailings [45-50]. Such studies are still being continued to increase the stream of tailings reused.

The recent analysis of the possibility of meeting the requirements of the closed-circuit economy indicated that in the case of flotation tailings, compliance with these requirements is excluded [51], due to the lack of the possibility of managing the entire tailing stream [1]. The authors pointed out that in the case of certain specific wastes, such as flotation tailings (including tailings from KGHM Polska Miedź S.A.), the implementation of this principle is impossible so far, despite the indisputable rightness of the closed-circuit economy philosophy.
4. Summary
Water and flotation tailing management at KGHM Polska Miedź S.A. has been taking place for over 60 years and is conducted through the Water and (flotation) Tailing Management System (WTMS). The system is the result of many years of experience and uses specific solutions, continuously adapted to the changing environmental, legal and technological conditions. In contrast to many global systems, the waters circulating in the WTMS come entirely from own company sources, mainly from the drainage of mines. The elimination of the need to intake additional quantities of water from the environment due to the use of own waters and recycling of technological waters allows for sustainable water management of KGHM Polska Miedź S.A. and fully complies with the principle of closed-circuit economy.

In the field of tailings disposal, both the technology currently used at Żelazny Most TMF and planned to be implemented at the South Quarter satisfactorily meet the requirements of both BAT and the “circular economy” principles. It became possible due to many years of experience and constant adaptation of applied technologies to the changing internal and external conditions.

5. References
[1] Grotowski A, Mizera A i Grotowska M 1995. Możliwości i warunki zagospodarowania odpadów wydobyczkowych powstających przy eksploatacji i przeróbce rud miedzi. Konferencja: Problemy Zagospodarowania Odpadów Mineralnych, Wisła.
[2] Grotowski A, Witecki K, Ziętkowski L i Rubaniuk A 2016. Dokumentacja Systemu Gospodarowania wodami kopalnianymi i przemysłowymi w ciągu górnico-przeróbczym KGHM Polska Miedź S.A. KGHM Cuprum Sp. z o.o. – report not published.
[3] Liu W, Moran C J & Vink S 2011. Quantitative risk-based approach for improving water quality management in mining. Environmental Science and Technology 45(17) pp 7459–7464.
[4] Moreno P A, Aral H, Cuevas J, Monardes A, Adaro M, Norgate T & Bruckard W 2011. The use of seawater as process water at Las Luces copper-molybdenum beneficiation plant in Taltal (Chile). Minerals Engineering 24(8) pp 852–858.
[5] Freitas A, Magrini A 2013. Multi-criteria decision-making to support sustainable water management in a mining complex in Brasil. Journal of Cleaner Production 47 pp 118-128.
[6] Aitken D, Riveria D, Godoy-Farúndez A, Holzapfel E 2016. Water Scarcity and the Impact of the Mining and Agricultural Sectors in Chile. Sustainability 8(128) pp 1-18.
[7] Valdés-Pineda R, Pizarro R, García-Chevesich P, Valdés J B, Fuentes R, Helwig B 2014. Water governance in Chile: Availability, management and climate change. Journal of Hydrogeology 519 pp 2538-2567.
[8] Kotarska I 2012. Odpady wydobycze z górnictwa miedzi w Polsce – bilans, stan zagospodarowania i aspekty środowiskowe. Czasopismo Naukowo-Techniczne Górnictwa Rud 4(65) pp 45-63.
[9] Jian-ming C, Run-qing L, Wei S & Guan-zhou Q, 2008. Effect of mineral processing wastewater on flotation of sulfide minerals. Trans. Nonferrous Met. Soc. China, 19, 454-457.
[10] Chavez-Crooker P, Obreque-Contreras J, Perez-Flores D & Contreras-Vera A 2015. Desalination Plants: Technology to Supply Water to Mining Processes and Local Populations, Opportunities and Environmental Impact. Current Biotechnology 4(3) pp 1-14.
[11] Quinn J J, Kracht W, Gomez C O, Gangon C & Finch J A 2007. Comparing the effect of salts and frother (MIBC) on gas dispersion and froth properties. Mineral Engineering 20 pp 1296-1302.
[12] Jeldres R I, Forbes L, Cisternas L A 2016. Effect of Seawater on Sulfide Ore Flotation: A Review. Mineral Processing and Extractive Metallurgy Review 37(6) pp 369-384.
[13] Yousef A A, Araf A M, Ibrahim S S i Khalek M A 2003. Sea Water Usage in Flotation for Minerals Beneficiation in Arid Regions – Simulation and Application. Proceedings of XXII International Mineral Processing Congress (Cape Town, RPA).
[14] Slatter K A, Plint N D, Cole M, Dilsook V, De Vaux D, Palm N & Oostendorp B 2009. Water Management In Anglo Platinum Process Operations Effects Of Water Quality On Process Operations. Abstracts of the International Mine Water Conference (Pretoria, South Africa).

[15] Jeldres R I, Forbes L, Cisternas L A 2016. Effect of Seawater on Sulfide Ore Flotation: A Review. Mineral Processing and Extractive Metallurgy Review 37(6) pp 369-384.

[16] Laskowski J S 1969. Chemia fizyczna w procesach mechanicznej przeróbki kopalni. Wydawnictwo Śląskie (Katowice).

[17] Castro S, Venegas I, Landero A, Laskowski J S 2010. Frothing in seawater flotation systems. Proc. XXV Int. Mineral Processing Congress (Brisbane) pp 4039-4047.

[18] Castro S, Ramos O, Cancino J P, Laskowski J S 2012a. Frothing in the Flotation of Copper Sulfide Ores in Sea Water. Water in Mineral Processing – Proceeding of The First International Symposium SME pp 211-223.

[19] Castro S, Toledo P and Laskowski J S, 2012b. Foaming Properties of Flotation Frothers at High Electrolyte Concentration. Water in Mineral Processing – Proceeding of The First International Symposium SME 51-60.

[20] Laskowski J S, Castro S, Ramos O 2014. Effect Of Seawater Main Components On Frothability In The Flotation Of Cu-Mo Sulfide Ore. Physicochem. Probl. Miner. Process. 50(1) pp 17–29.

[21] Muzenda E 2010. An investigation into the Effect of Water Quality on Flotation Performance. International Journal of Chemical and Molecular Engineering 4(9) pp 562-566.

[22] Lekki J, Laskowski J S 1975. Wpływ chlorku sodu w wodach kopalnianych LGOM na flotację rudy miedzi. Physicochem. Probl. Miner. Process 5(1) pp115–123.

[23] Fourie A 2009. Preventing catastrophic failures and mitigating environmental impacts of tailings storage facilities. Procedia Earth and Planetary Science PROEPS 1(1) pp 1067–1071.

[24] Yilmaz E 2011. Advances in reducing large volumes of environmentally harmful mine waste rocks and tailings. Gospodarka Surowcami Mineralnymi 27(2) pp 89-111.

[25] Collective elaboration 2017. Mine Environment Neutral Drainage (MEND) Project - Study of tailings management technologies. Klohn Crippen Berger (Canada).

[26] Davis M 2011. Filtered Dry Stacked Tailings – The Fundamentals. Proceedings Tailings and Mine Waste 2011 (Vancouver, Canada).

[27] Thompson N & Moreno P 2017. Thickened Tailings Deposition for Closure. 20th International Seminar on Paste and Thickened Tailings (Beijing, China).

[28] Martin T E, Davies M P, Rice S, Higgs & Lighthall P C 2002. Stewardship of Tailings Facilities. Mining, Minerals and Sustainable Development 20.

[29] McPhail G 2015. The high density thickened discharge tailings storage facility at Osborne Mine – a case history from inception to closure. Proceedings of the 18th International Seminar on Paste and Thickened Tailings (Cairns, Australia).

[30] Davis M, Lupo J, Martin T, McRoberts E, Musse M & Ritchie D 2010. A Dewatered Tailings Practice –Trends and Observations. Proceedings of Tailings and Mine Waste ’10 (Vail, , USA).

[31] Park J H, Han Y S & Ji S W 2018. Investigation of mineral-processing waste water recycling processes: A pilot study. Sustainability 10(9) 1–10.

[32] Raposo N, Bahia R, Afonso E & Topa Gomes A 2014. Optimization of thickened tailings deposition. Proceedings of Paste 2014 (Vancouver, Canada).

[33] Lepoudre D C 2015. Examples, Statistics and Failure modes of tailings dams and consequence of failure. SNC LAVALIN, REMTECH - October 15.

[34] Larrauri P C & Lall U 2018. Tailings Dams Failures: Updated Statistical Model For Discharge Volume and Runout. Environments 5(28) 1-10.

[35] Pomykała R & Tora B 2017. Circular economy in Mineral Processing. Proceedings of Mineral Engineering Conference 2017 (Wisła, Poland).

[36] Matinde E, Simate G S & Ndlovu S 2018. Mining and Metallurgical wastes: a review of recycling and re-use practices. The Journal of the Southern African Institute of Mining and Metallurgy 118 pp 825-844.
[37] Tayebi-Khorami M, Edraki M, Corder G & Golev A 2019. Re-Thinking Mining Waste through an Integrative Approach Led by Circular Economy Aspirations. Minerals 9(286) pp 1-13.
[38] Czaban S, Lewiński J, Rubaniuk A & Tarasek W 2008. Składowiska Odpadów. Monografia KGHM Polska Miedź S.A. pp 855-877.
[39] Collective elaboration 2013. Western Australian water in mining guideline. Department of Water (Australia) 12.
[40] Cusano G, Gonzalo M R, Farrell F, Remus R, Roudier S & Sancho L D 2017. Best Available Techniques (BAT) Reference Document for the Non-Ferrous Metals Industries. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control)
[41] Stefanek P, Serwicki A 2014. Ograniczenie oddziaływania OUOW Żelazny Most na środowisko poprzez zmianę technologii składowania odpadów. Workshops: Górnictwo-człowiek-środowisko pp 394-406.
[42] Chambers D M & Higman B 2011. Long Term Risks Of Tailings Dam Failure. http://www.csp2.org/technical-reports/
[43] Stefanek P & Wrzosek K 2015. Zmiana technologii składowania odpadów w procesie rozbudowy Obiektu Unieszkodliwiania Odpadów Wydobywczych Żelazny Most. Inżynieria Morska i Geotechnika 3 pp 382-386.
[44] Hansen K, Braungart M & Mulhall D 2012. Resource Repletion. The Springer Encyclopedia of Sustainability Science and Technology.
[45] Janiec R & Nowak J 1973, Odpady z przeróbki rud i ich mieszaniny z piaskiem jako materiał podsadzkowy. Rudy i Metale Nieżelazne 9(18) pp 428-432
[46] Chmielewski T, Grotowski A, Kołodziej B & Adamski Z 1995. Możliwości zastosowania ługowania cyjankowego do odzysku miedzi z odpadów flotacyjnych. Rudy i Metale Nieżelazne 8(40) pp 318-321.
[47] Kudelko J, Nitek D 2011. Wykorzystanie odpadów z działalności górniczej jako substytutów surowców mineralnych. CUPRUM - Czasopismo Naukowo-Techniczne Górnictwa Rud 3(60) pp 51–64.
[48] Raciborski R 1975. Badania przydatności odpadów flotacyjnych Lubińsko-Głogowskiego Okręgu Miedziowego do mas bitumicznych - część I. KGHM Cuprum sp. z o.o. – report not published
[49] Szczap J 1997. Gospodarcze wykorzystanie odpadów flotacyjnych do dosadzania starych zrobów zawalowych przy pomocy instalacji rurowych w O/ZG "Lubin". KGHM Cuprum sp. z o.o. – CBR – report not published.
[50] Dobrzański J, Garbaczewski J, Grotowski A, Mizera A & Piątkowski J 1999. Gospodarka odpadami w KGHM Polska Miedź S.A. bilans odpadów, technologie wykorzystania, efekty ekonomiczne i ekologiczne – stan i perspektywy. V Conference - Problemy zagospodarowania odpadów mineralnych (Wista).
[51] Kotarska I, Mizera B & Stefanek P 2018. Mining Waste in the Circular Economy – Idea Versus Reality. Proceedings of Illrd International Innovative Mining Symposium (Kemerovo, Russian Federation) 41 pp 1–7.