Earthquake Impact on Tailing Dam Stability i.e. Environmental Pollution

Conference Paper · August 2018

CITATIONS
2

READS
153

3 authors, including:

Kemajl Zeqiri
University 'Isa Boletini", Mitrovic
10 PUBLICATIONS **5** CITATIONS

SEE PROFILE

Earthquake Impact on Tailing Dam Stability i.e. Environmental Pollution

PhD can., K. Zeqiri, Associate Professor Dr., B. Dimiskovska & Professor Dr., M. Garevski
Institute of Earthquake Engineering and Engineering Seismology, IZIIS, University "Ss. Cyril and Methodius",

PD Dr habil., F. Riesbeck
Humboldt-Universitat at Berlin

ABSTRACT:
There is a based assumption that, one of the important factors of environmental pollution, is a pollution caused from earthquake impact on tailing dam stability, i.e. the main objective of this study is to treat the earthquake impact on the environmental pollution, caused as result of tailing failure. This study also paid attention on humane life losses by tailing failure and economical damage in this case.
The study has been based in the literature research and author's experience as well, the aim of this study is treating earthquake impact on environment pollution and disasters, so due to mostly of tailings failure worldwide, caused victims and lots of objects damaged, this fact proves that, tailing failure is much more than environmental pollution. Tailing failure causes humanitarian catastrophes, environmental disasters and finally environmental and social crises.
These facts have to have influence on improving of tailing management system, via treating of security of the tailing dams, as part of tailing management facilities and mines circle life, this way tailing management, should expand institutions stakeholders, for e.g. including also the institutions for National Protection Agencies. Take into consideration that, tailing dams has also the cross border impacts; countries should setting up the unique standards for tailing facilitates management and maintenance.
Improving of tailing dam security will avoid environmental disasters and degradation, natural catastrophes, humane losses and finally economic losses i.e. economic recessions.

Keywords: *earthquake, environment, tailing dam, failure, disaster, stability, management, security, economy etc.*

1. INTRODUCTION

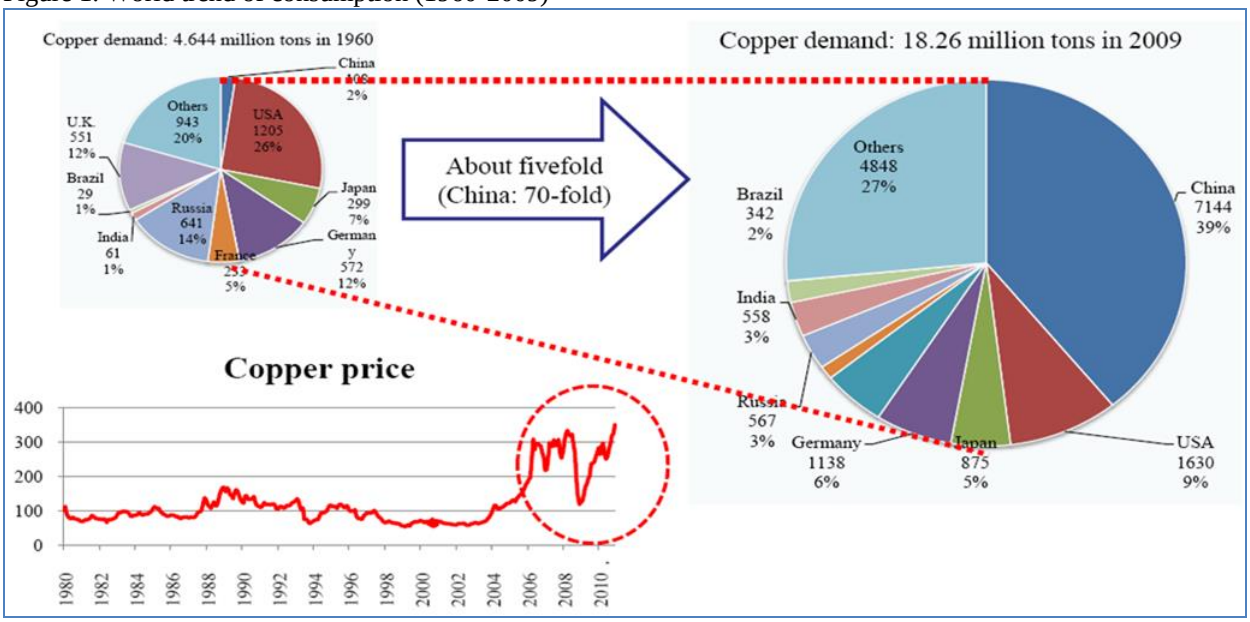
The industrial revolution during the 19th century and especially in the 20th century boosts the country's economy (GDP) very fast. Part of this industrialization without doubt, was mining industry.

Historically the humane society has been based in the mining industry i.e. mining products. During second part of the 20th century, the mining industry i.e. mining products have had a rapid development. It is for sure, the mining development had a strong impact on economy development of particularly countries[1].

[1] Zeqiri, K. Global Market as an Efficient Factor for Mineral Resources Management, Pristine, 2012, - Item view http://www.kolegjiglobus.com/?page=1,37#

The resources consumption have been raised five to six fold, between years 1960-2009, for e.g. copper demand was raised for 393% from 1960 up to 2009 (see fig. bellow)[2].

Figure 1. World trend of consumption (1960-2009)

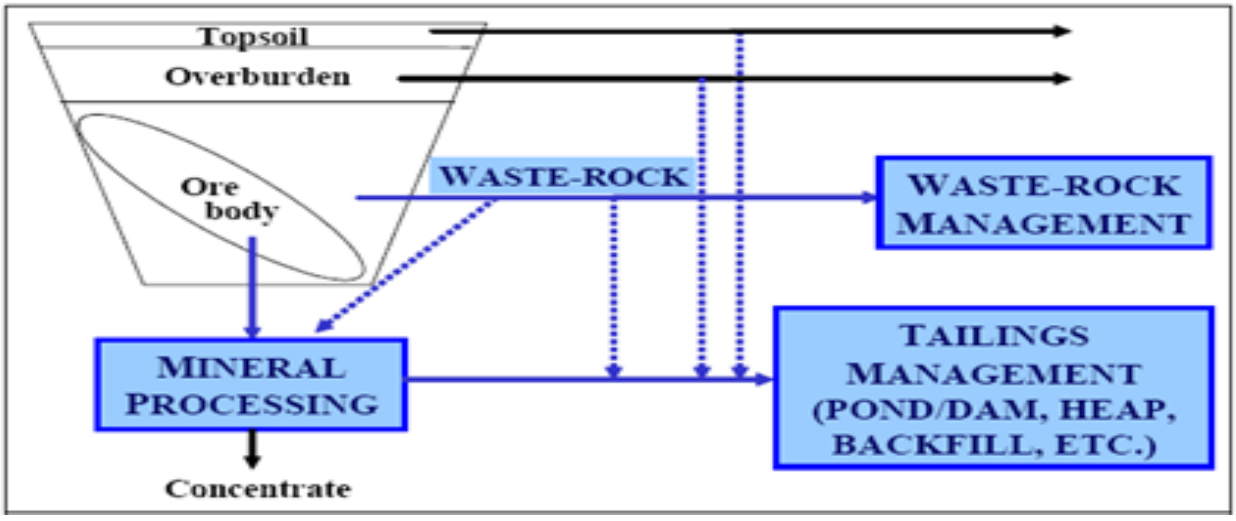


Due to these facts countries worldwide developed mining industry, in order to get fast economic growth but, beyond of that mining industry has had strong negative impact in the environment, including air, soil and water pollution, up to causing natural and humanitarian disasters.

One of the biggest environmental polluters is a tailing dam. Tailing dams are the fine-grained waste material remaining after the metals and minerals have been recovered (extracted) from mineral (ore) via various technical processes. The ore (minerals) is processing via technological process of girding, milling and floating process, so usually this process and with lots of waste (more than 90% of treated material/ore). This waste is in the form of slurry (combined of solid waste and water); operators transports it, via pumping system, to the disposal process which ends with creation of so called tailing dams (see diagram below).

[2] Ministry of Economy Trade and Industry – Japan, Tokyo, 2012.

Figure 2. The process of tailing (waste) creation.



According to current statistics, there are about 3,500 tailing dams worldwide, with different contents depending on what kind of minerals have been exploited[3].

2. MATERIALS AND METHODS

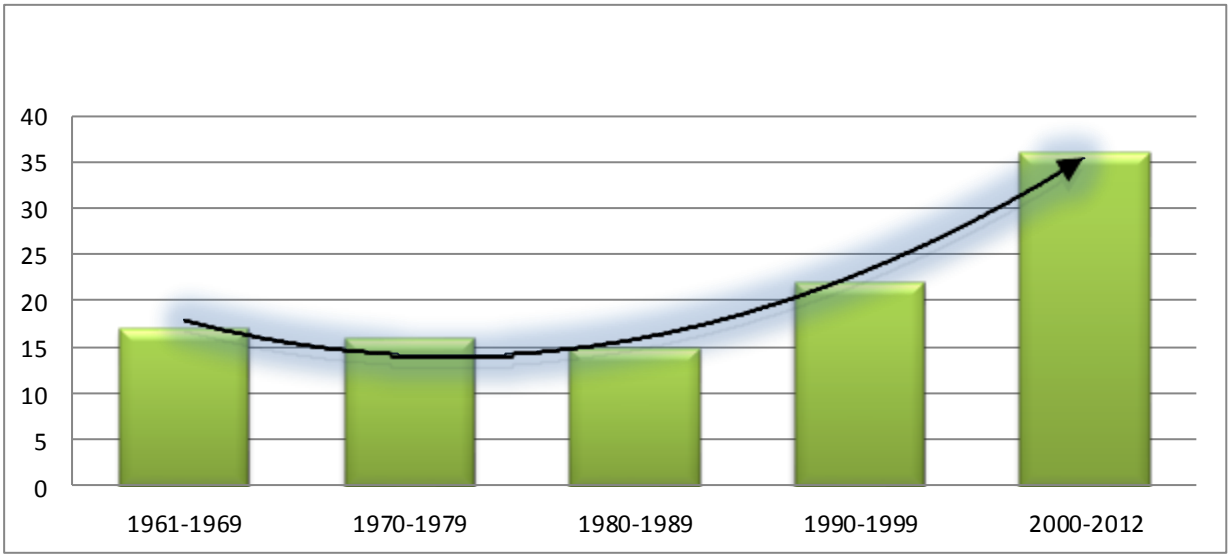
This study has been based on literature research, almost in the literature related to tailing dam's i.e. mining waste management and author's experience. So, mineral resources played an important role in the country's economy. So far, this industry left behind lots of environmental problems, as are tailing dams.

Abounded, insecurity and not remediated tailings lies worldwide, these tailings permanently affect our space of life, vie pollution and contaminating air, water and soil. This permanent pollution on environment for sure have had impact on manifestation of several illnesses, carried out from high content of metals and other polluters in air, water and soil.

Nowadays, fortunately most of the countries are aware about this; it has been developed lots of legislations/standards/guidelines for environment protection from mining activities i.e. tailing management, with aim to reduce of tailing impact on environment and humane health as well, so far the information about tailing remediation and rehabilitation are not promising, on the other hand there are lots of statistics for tailing dam failure around the world (see chart below).

[3] http://www.pbs.org/wgbh/pages/frontline/environment/alaska-gold/tailings-dams-where-mining-waste-is-stored-forever/

Figure 3 . Trend of tailings dams failure



The chart shows that, tailing failure trend is progressively rising, despite the progress achieved in the field of legislation framework for environment protection from mining industry. It can be assumed the fragility of tailing risk assessment i.e. tailing dam management system.

Until the tailing dams themselves cause pollution and contamination, tailing dams failure cause not only pollution, but *environmental disasters, humane lives losses and finally economic regression*.

3. TAILING DAMS FAILURE WORLDWIDE

In the early of the '70s, the "bill" of economic growth, from mining industry starts to come back to the several countries, or being more specific the "bill" of none paying attention on tailing dam security and stability in the process of tailing dam construction.

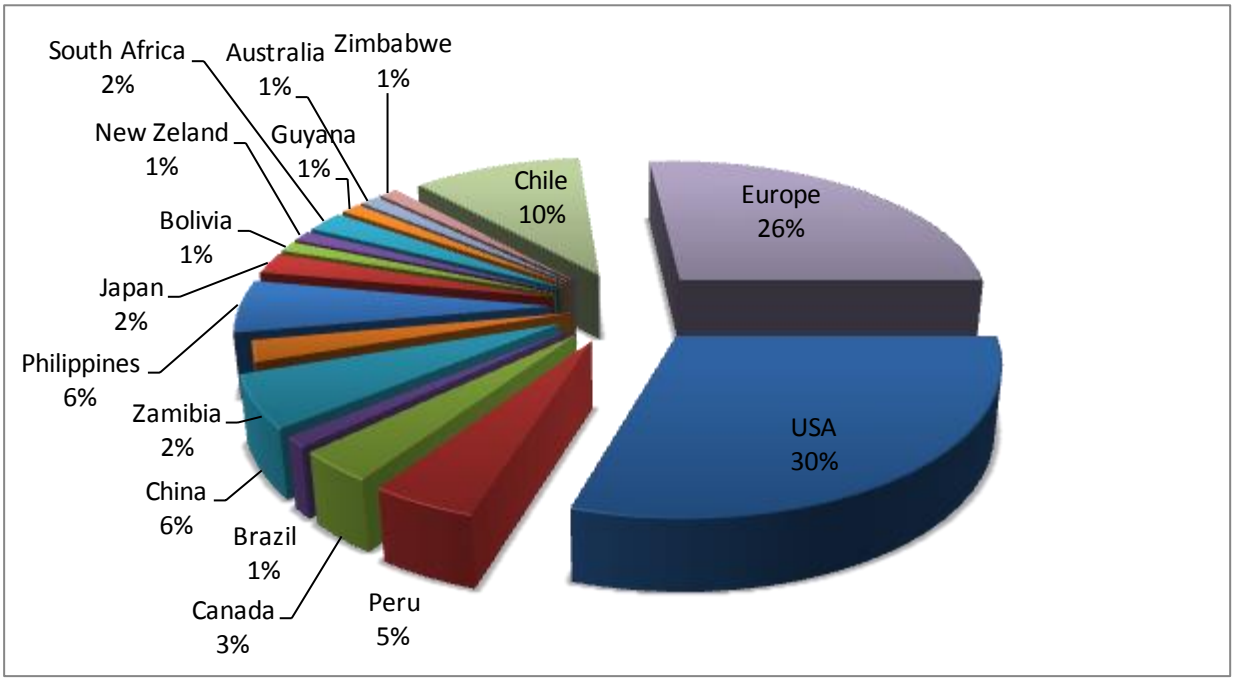
Thousands tailings waste worldwide, in the beginning of '70s, starts to occur not only as permanent "slower polluter" but as a "fast and destroyed polluter".

Tailing dams start its failure, broking this way the geotechnical stability. It can be listed hundreds of factors for broking of tailing dam stability (overtopping, problems with seepage, heavy rain, lack of foundation, earthquakes etc.*), but it is for sure, for tailing dam failure, cannot be responsibility a nature, or even that, physical events, the responsibility lies behind of lack of risk management calculation, or even that; missing of management risk in the process of tailing dam construction and disposals process*.

According to the available statistics and documents, the first tailing dam failure was recorded in 1961, in Tymawr - United Kingdom, it should be noted that, for this tailing failure have been not given more dates, related to damages cared out or environmental negative impacts.

From 1961 till 2012, have been recorded more than 100 (hundred) tailing dams failure worldwide. In the USA are recorded 26 tailings failure, In Europe 23, Chile 9, Canada 3 while in Australia just one, below is given relate chart.

Figure 4. Percentage of tailing failures worldwide

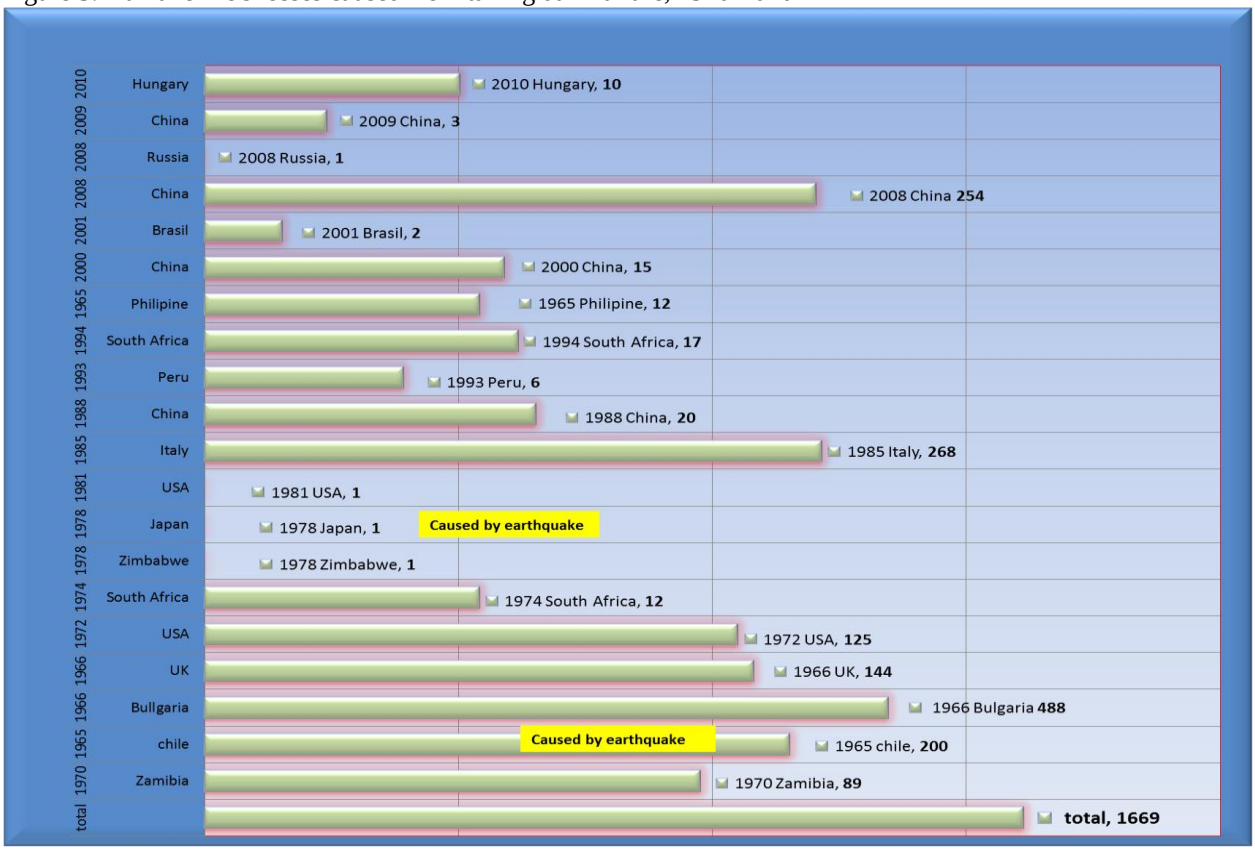


More than 55% of tailing failures have been located in Europe and US; this fact proves our above statement, that mining industry served as engine of economy, take into consideration economy development of USA and European Countries. Otherwise even countries as Australia and Canada are known with mining industry there have been recorded just a few tailing failure, this fact can be used as positive indicator of the level of tailing management system in these countries.

2.1. Tailings Failure Impacts on Humane Life Losses

From about 90 tailings failure worldwide, treated in this paper, 20 of them caused humane loses and injures, which means that more 20% of number of recorded tailing failure worldwide cased about 1669 victims and many injured people.

Figure 5. Humane life's losses caused from tailing dam failure, 1970-2010



2.2. Earthquake Impact on Tailings Dam Failure i.e. Environmental Pollution and Economic Regression

About 20% of recorded tailings failure, between 1960-2012 caused directly from earthquake events. In Chile six tailings failure happened, from one earthquake events, in 1965 year. Thus, different types of tailings dams failed from earthquake effect, as result of liquefaction of tailing's material[4], so in this case behind of environmental and economic damage, tailings failure left behind about 200 killed people.

Based in the worldwide fact-statistics, there can be reached statement about tailings failure; *tailing dams' failure cause, natural disasters and catastrophes, this way is exceeding concept of the statement about the environmental pollution from tailing dam's failure*. It is clearly that, environmental pollution is one of the tailing failure's outputs, but treating the tailing dam's failure just in the concept of environmental pollution, is not realistic any more.

With regard to earthquake impact on tailing failure, it should be taken into consideration that earthquake, has at last two effects of its impact into tailing dam stability: *the first* (i) *direct impact, which instantly causes dam failure and the second* (ii) *indirectly impact, which have impact on weakening of dams stability'(broking of cohesive forces), this way over entire length and width of the tailing body, stimulates*

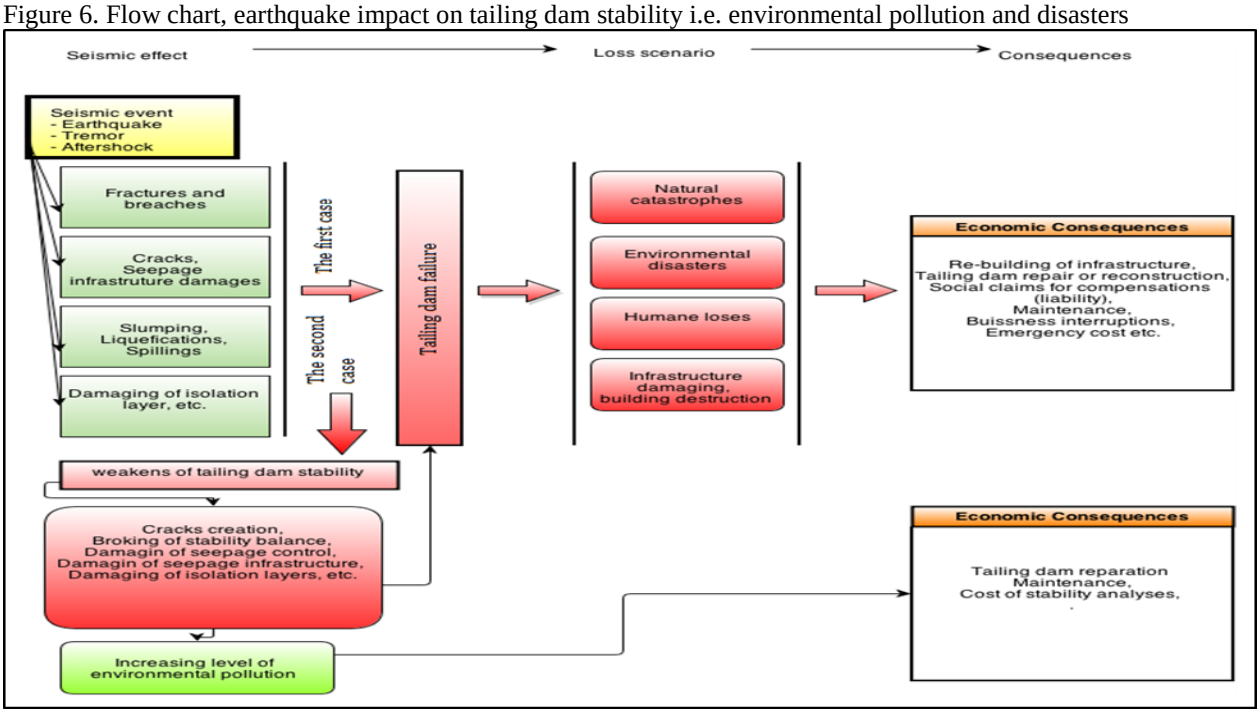
[4] Tailings Dam Incidents, U.S. Committee on Large Dams - USCOLD, Denver, Colorado, ISBN 1-884575-03-X, 1994, 82 pages [compilation and analysis of 185 tailings dam incidents]

or creates: fractures, cracks, liquefaction spilling etc. up to causing of local tailing body's slides, damaging of isolation layer and seepage infrastructure.

So, until in the first case (i), earthquake cause instantly tailing failure i.e. natural catastrophes and disasters up to humane losses, in the second one (ii) earthquake, weakens tailing dam stability, being this way as a relevant factor for eventually future dam failure. On the other hand, damaging of seepage infrastructure, isolation layer etc., indirectly increase contamination of underground water, i.e. environmental negative impact.

Obviously, there is no doubt that earthquake has impact on the tailing dam stability i.e. environmental pollution and disasters, even this impact could be instantly or background (which almost increases environmental pollution and stimulate tailing failure).

Figure 6. Flow chart, earthquake impact on tailing dam stability i.e. environmental pollution and disasters



2.2.1. Environmental Impact

Every outside force which, attempt to break the *"tranquility status"* of the tailing dam, indirectly causes the environmental pollution.

As result of earthquake impact, in the tailing dam body appears: fractures, breaches, cracks etc. which depends from the forces of the shock waves, can causes instantly tailing failure, sub failure or just breaking of insides stability forces of tailing dams. As it showed on the above (fig.5), in the both cases, earthquake impact in tailing dam cause environmental pollution.

In the first case, impacts in the environment are very high and with unpredictable consequences, which almost are non-measurable (e.g. Tailings failure: Chile in 1965, Bulgaria in 1966, Italy in 1985, China 2008, Hungary in 2010 etc.).

The second one (background effects), depending from the tailing compatibility create condition for increasing level of environmental pollution. As it can see in the flow chart (fig.5), the background earthquake effect could be a main factor for later dam failure. So, even "background" effect, could increase the level of pollution, the situation is "under control" therefore the environmental negative impact is significantly lower, than in the first case.

2.2.2. Economic impact

According to the statistics for tailing failure presented in this paper (even there is lack of economic dates), approximately calculation carried out, proves that tailing failure left behind, number of victims (social problems), contaminated areas, destroyed infrastructure, business interruptions which normally cause economical negative impacts. Before presenting of key study calculation related to economic impact of tailing dam failure, let us analyze dimension of this impact, which at last could be on three dimensions, as cost of:

1. Emergency impact, including business interruption
2. Infrastructure rebuilding or repairing
3. Long term of environmental and social impact, including claims and liabilities

Take into consideration these three dimensions of economic impacts, it can be concluded that determination of cost-impact from tailing failure is complex and difficult to determine.

Table 1. Approximately estimated tailing failure cost

Cost of: Emergency impact including business interruption	**Cost of: Infrastructure rebuilding or repairing**	**Cost of: Long term of environmental and social impact including claims and liabilities**	**Cost of: Total approximately economic impact for one tailing failure**
75,182,785.19 €	252,564,116.50 €	*6,848,517.52 €	334,595,419.21 €
*<u>*Notes*</u>: there is not included impact-cost of business interruption and impact-cost of claims and liabilities, and animal loses.			

The calculation is based just in literature research, for dam failure worldwide[5]; there have not been any "in situ" estimation. As calculation parameters have been take into consideration number of victims (life loses and injured victims), reported infrastructure damaged or destroyed, number of evacuated people, contaminated of drinking water i.e. cost for treating of contaminated water and soil from high metals content.

Take into consideration parameters included or not included in this calculation the margin of errors could have significant movements. Nevertheless, above analyses shows that, tailing failure has significantly impact in the country's economy that could be hundreds of million euros, causing thus long term negative impacts with a chain effects.

[5] Tailings Dam Incidents, U.S. Committee on Large Dams - USCOLD, Denver, Colorado, ISBN 1-884575-03-X, 1994, 82 pages [compilation and analysis of 185 tailings dam incidents]

3. RESULTS AND DISCUSSIONS

Obviously, results from this paper work, can be gathered into main concepts; the first (i) earthquake effect on tailing failure is crucial and very important factor for tailing dam stability. At last, earthquake impact in tailing stability could occur in two cases:

1. *Instantly impact; which almost cause natural catastrophes, disasters, humane losses and associated with unpredictable economic losses.*
2. *Background impact; which almost tent to break stability of tailing dam i.e. damaging of infrastructure in whole of tailing body. This way creates conditions for increasing of environmental pollution and being an important factor (earthquake) for eventually later tailing failure.*

The second one (ii), tailing failure exceed the concept of "environmental pollution from tailing failure), because results and facts presented in this paper, shows that; tailing failure cause more than pollution, e.g. natural catastrophes, disasters, human loses and huge economical negative impacts.

So the main discussions, that this paper-work tent to raise is; *statement of new concept for tailing failure*, when the environment pollution, will be just one of the important "*outputs*" of tailing failure. Thus, will increase institution's awareness about tailing failure, consequently will bringing up developing of new methods, for tailing risk management i.e. tailing dam security with a aim, for avoiding and prevention of tailing dam failure.

4. CONCLUSIONS

I. It is evident permanent growth of mineral production. This way, the mining waste will be increased i.e. will increase number of tailing dams worldwide.
II. Tailing dam failure worldwide left behind lots of environmental catastrophes, victims and finally economic regressions.
III. Trend of tailing dam failure is progressively increased, from '60s when has been recorded a first dam failure. Dramatically increasing is showed between '90 to '99s and '00 to '12s.
IV. The earthquake impact on tailing dam stability i.e. tailing failure is significant and crucial for tailing security and stability.
V. The earthquake impact could appear in two cases, first one (i) "instantly" (which automatically cause tailing failure) and second one (ii) as "background" impact (which create significant damages in tailing stability)
VI. The finally "output" of tailing failure is not just environmental pollution. Tailing failure, cause: natural catastrophes, disasters, humane losses, unpredictable economic losses and long term environmental pollution.
VII. Tailing failure is not "*product of nature*". Lack and fragile Tailing Management Facilities (TMF), is a main factor for tailing failure. So, in order to ensure long term tailing stability and security, the research work should be directed on improving of long term tailing stability as part of TMF.

5. REFERENCES

Romo, J. M. (2008). Geo-Seismic Environmental Aspects Affecting Tailings Dams Failures. American Journal of Environmental Sciences, 212-222.

Implications of Earthquakes on the Stability of Tailing Dams. (2007, November 12-14). Yerevan, Armenia: Univeristy of Munster Gelogical-Palaeontological institute. Correnssstr.24, 48149 Munster, Germany.

Environmetal Disaster looms in Kutahya after tailing failure. (9 May 2011). *Today's Zaman*.

Agriculture, U. S. (September, 2000). *Heavy Metal Soil Contamination.*

Anders Rydergren, M. M. (Octomber, 2004). *Environmental Remediation at Paddock Tailings Area, Gracanica Kosovo.* Prishtine: SIDA.

Davies, M. P. (September, 2002). Tailings Impoundment Failures:. *WASTE GEOTECHNICS*.

Gavett, G. (July 30, 2012). Tailings Dams: Where Mining Waste is Stored Forever. *Frontline*.

Irusta, D. H. (n.d.). The cost of wastewater reclamation and reuse in agricultural production in the Mediterranean countries.

(January, 2009). *Managment of Tailings and Waste-Rock in Mining Activities .* European Commission .

JURY, R. D. (n.d.). *SEISMIC HAZARD ASSESSMENT - PRACTICAL CONSIDERATIONS.* 12WCEE,2000.

Kelmendi, S. (2002). *struktura e formimit te vendburimit.* Prishtinë.

Liesbet van Cauwenberghe and Diane S Roote, P. (October, 1998). *In Situ Bioremediation.* Ground-Water Remediation Technologies Analysis Center.

Liesbet van Cauwenberghe and Diane S Roote, P. (Octomber, 1998). *Ground-water Remediation Technologies Analysis Centre.*

Peck, P. (November 2004). *Reducing Environment & Security Risks from Mining in.* UNEP.

Robinsky. (1979). *Tailings Dams Risk of Dangerous Occurrneses.* Paris: Commission Internationale des Grands Barrages – 151, bd Haussmann, 75008 .

Zeqiri, K. (2011). Global Market as a Factor of the Efficient Mangagment of Mineral Resources. *Globus*, 13.

(n.d.). Retrieved from http://www.unep.org/dtie/.