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MINING AND GEOSYNTHETICS: EMERGING TECHNOLOGIES, GROWING MARKETS[i]

M. E. Smith[ii], Vector Engineering, Inc., USA and Peru

ABSTRACT

The author explores the recent trends in mineral production and how that has affected geomembrane. Continuing trends in mining technology, geographical expansion and environmental protection are then considered in light of increasing total gross domestic product (GDP), mineral demand and other trends to estimate demand for geomembranes in the coming decades.

1. INTRODUCTION

The last decades have brought amazing change in the mining industry, touching every aspect of the business, not the least of which has been the role of geosynthetics. From the size of the industry to expanding types of applications to increased technology sharing between mining and solid waste management. Mining has been a catalyst for change, pushing technology, expanding geographical boundaries, and helping in key ways to build the geosynthetics industry.

For those not familiar with mining applications, let us review some of the major applications for geomembranes. Without trivializing the other important mining applications, by sheer scale if for no other reason, one must focus on heap leach pad liners for gold and copper ores. Technologies advanced through heap leaching in the last 20 years include:

- Secondary copper sulfide ore (eg, chalcocite, Cu2S, and covellite, CuS) heap leaching;
- Temporary exposed geomembrane covers, or “raincoats”, for tropical sites;
- Heap leaching copper oxide ores, using interlift liners for multi-lift heaps to control acid consumption;
- Valley fill leaching (VFL) for gold and silver ores, with aggressive liner and drainage systems and very high loads;
- Deep conventional heaps, now exceeding 160 m and at densities of over twice that of municipal solid waste;
- Larger heap leach and salt evaporation facilities, with ponds and leach pads now measured in square kilometres;
- Geopipe applications now routinely designed for over 100 m burial depth;
- GCLs reducing the reliance of compacted clay liners;
- From the first lined heap leach project in about 1963 until 1987, there were fewer than 50 full scale lined heap leach projects constructed, with an average size of perhaps 100,000 square meters (m^2) for a total lined area of about 3 million square meters. These first leach pads used liners as thin as 0.4 mm;
- From 1987 until now there have been at least 120 more full-scale projects with the largest exceeding 4 million m^2 and the total installed base liner area on the order of 60 million m^2 - or 60 square kilometres. Essentially all of these leach pads used geomembrane liners and the average thickness is now about 1.5 mm.

Some of this growth was driven by increased metal prices, but most occurred during a general crash in the metals markets (see Fig. 1). From the mid 1980s through 1997 gold, as an example, consistently traded above US $350 per ounce and averaged about US $400. In early 1997 the gold market collapsed and the price fell to a low of US $260, not again reaching US $350 until the 2003 (or 2005 considering constant dollars). Copper followed an almost identical trend, first climbing to about US $1.33 per pound, then collapsing to a low of US $0.58 and not again breaking through $1.00 until December 2003. Yet these same years saw geosynthetics use in mining increase and diversify. In part through the wide-spread commercialization of heap leach technology to process lower grade resources, and in part through more rigorous environmental controls, driven both by regulation and by improving corporate governance. In fact, to a great extent the low metals prices drove the increasing demand; as the mines struggled to remain profitable they increasingly relied on the most successful, low-cost processing technology, heap leaching. As metal prices began to recover about three years ago, they continued to optimize and expand that technology.

Figure 1: Historic Gold Price, USD per troy ounce

2.0 THE NEXT DECADE

As this paper is being drafted we are seeing one of the most amazing periods in modern mining. Expanding geography as more countries liberalize their economies and overcome political risk. Expanding environmental controls as regulatory bodies increase oversight, mining companies continue to improve their own governance, and the role of social and NGO participation increasing as the definition of stakeholders broadens. Expanding technology as the industry exploits mineral deposits in increasingly challenging circumstances. And, of course, expanding mineral demand is being driven by increasing Western GDP and the emergence of China and India as major economies.

2.1 Expanding Geography

Modern heap leaching was first commercialized in the US in the 1960s and the original boom in its use was in the gold fields of Nevada in the 1980s. The technology was then adapted to copper and broadly applied in Northern Chile. For years those two locales, Nevada and Chile, where home to the vast majority of all heap leach projects. Now we are seeing this technology applied throughout the Americas and beyond, including Australia, Canada, Mongolia, the Philippines, Indonesia, Burma, Turkey, West Africa, Russia and the former CIS nations. A list of some of the more advanced projects in planning with their home countries helps to highlight this point (see Table 1). The total number of pending projects almost certainly exceeds 250.

2.2 Expanding Environmental Controls

Pressure from the regulatory community, non-government organizations (NGOs) and community groups, and a general industry move towards better environmental stewardship has raised the bar considerably for containment systems. This is highlighted by some examples as listed in Table 2. One result is a general increase in the level of containment used for processing ore and disposal of mine wastes. For example, before about 1985, tailings impoundments rarely used geomembranes. The trend in the USA and Canada since then has been an increasing use of partially- or fully-lined tailings impoundments, especially for gold-cyanide and uranium mill tailings; however, outside of the USA and Canada tailings disposal design continues to principally use unlined impoundments. There seems to be a change, however, and as of this writing the author knows of at least eight tailings projects in design that include geomembrane liners, ranging from Argentina to Nicaragua and from Turkey to Indonesia.

Table 1: Heap Leach Projects in Advanced Planning

Country	Mineral or Metal	No. of Projects
Africa	Ag, Au	~15
Australia	Ag, Cu, Ni/Co, U	15+
Canada	Ag, Au, Cu	10+
Mexico & C. America	Au, Ni/Co	~15
China	Ag, Au, Cu, Zn	>50?
Europe/Middle East	Au, Cu, Ni/Co, U	~20
Russia & Uzbekistan	Cu, Au, U	~10
South America	Au, Ag, Cu, Ni/Co, U, NO_3, Zn	40
Southeast Asia	Au, Cu, Ni/Co	~10
USA	Ag, Au, Cu	15+

Table 2: Examples of Advancing Environmental Standards

Country	Example
Argentina	Some provincial governments require electrical leak location (ELL) on case-by-case basis; Double liner systems required for liners with more than nominal hydraulic head with very low maximum permissible leakage through primary liner of such system; Some jurisdictions prohibit cyanide or acid leaching and the federal standard for allowable cyanide in discharge waters is the lowest in the world; Environmental baseline and impact studies required; Public hearings on new projects required.
Brazil	Environmental baseline and impact studies required; Aggressive mine waste classification protocols; Public hearings on new projects required; Closure standards equal or exceed those of the USA and Canada.
Peru	Requires ELL surveys on case-by-case basis; Environmental baseline and impact studies required; Closure bonding required. Public hearings on new projects required.
Turkey	Applying EU-style standards to heap leach containment systems; Among the most stringent earthquake design standards in the world. Broader requirements for the use of double lined systems than most countries.

2.3 Expanding Technology

The prolonged low metal prices of just a few years ago coupled with the recent, dramatic increase in demand and prices have driven technology in surprising ways. A decade of following what seemed like ever-declining prices pushed companies to get better at extracting metals at low cost; the current boom allows those same companies to more broadly apply the technologies developed in the lean years. Copper, which is the largest consumer of geosynthetics in the mining industry, has added processes for re-leaching spent heap leach ore (called “ripios” in Spanish). Processing of oxide copper ores at very large scales (rather than the traditional secondary sulfide minerals) requires the use of thin liners between each lift on a leach pad to reduce acid consumption (and acid prices are climbing faster than metals prices, climbing from $15 per tonne in 2000 to nearly $500 per tonne in early 2008); while these interlift liners are very thin they are used in vast quantities, often exceeding the base liner area by 10 times. And a push out of Chile’s Atacama desert to subtropical and tropical locales has, for the first time, lead copper producers to consider temporary exposed geomembrane covers (“raincoats”) for heaps in wetter climates.

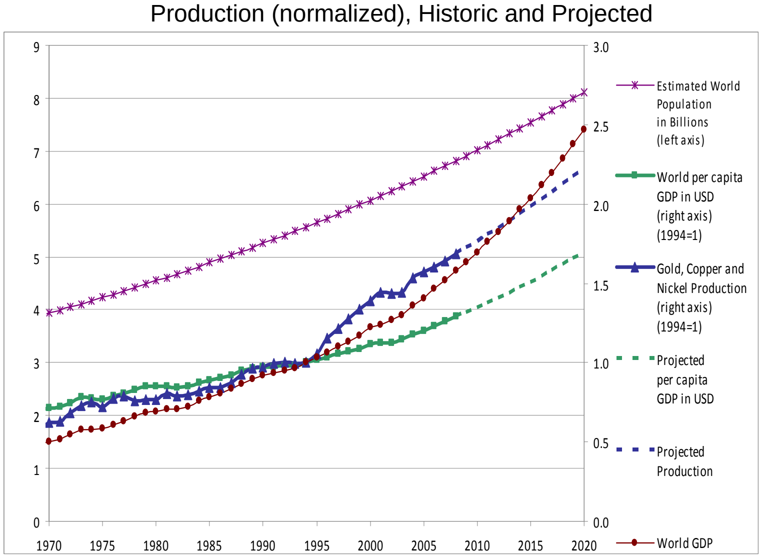
The limits of heap leaching itself are being tested by finding new minerals to process. The first large scale project to heap leach primary sulfide copper (eg, chalcopyrite, $CuFeS2$) ores was commissioned less than 5 years ago and will be the largest heap leach pad in the world when fully constructed; several other major projects are now in planning. Uranium and nitrates have been successfully leached and this use is expected to expand. Zinc and nickel are in experimentation and pilot or small-scale commercialization, and the potential for heap leaching to revolutionalize laterite nickel production in the same way it did for copper is now becoming recognized. Outside of China (it’s very difficult to get good numbers for inside) there are at least 15 nickel heap leach projects in planning and the typical leach pad size is 1 million m^2. Nickel ores require thin lift leaching due to high acid consumption and low permeability, and thus interlift liners will also be required. Most of these sites are in high rainfall locales which will require raincoats. And closure will require well developed capping systems.

There is also a continuing movement towards more aggressive waste containment for tailings and waste rock. The most obvious application is for acid generating wastes which benefit both from a good quality liner system to isolate leachate during operations and an aggressive cap to prevent formation of acid by limiting the inflow of – not water but – air. While heap leaching will probably remain the largest mining application for geosynthetics, the other applications will experience significant growth and diversity in the coming decade.

2.4 Expanding Mineral Demand

Considering historic demand, something fundamental changed in the late 1990s. In 1992 the first of the large scale copper heap leach projects come into production and by 1995 world copper heap leach production doubled. In 1994 the strong growth of the US economy drove increasing demand, which was then followed by economic recovery in Europe and continued strong demand from the Pan Pacific countries. Declining prices after 1995 intensified the use of heap leaching. Temporary issues of oversupply or shortages aside, mineral demand is a function of three principal drivers: population, per capita GDP, and technological advancements. The relationship between mineral demand and population, assuming flat per capita GDP, is proportional. However, as per capita GDP increases so does per capita demand for minerals, in part through increased reliance on technology (increasing per capita GDP generally follows increasing industrialization) and in part due to more luxuriant lifestyles. The net effect is metals demand exceeding population or total GDP, as illustrated in Figure 2.

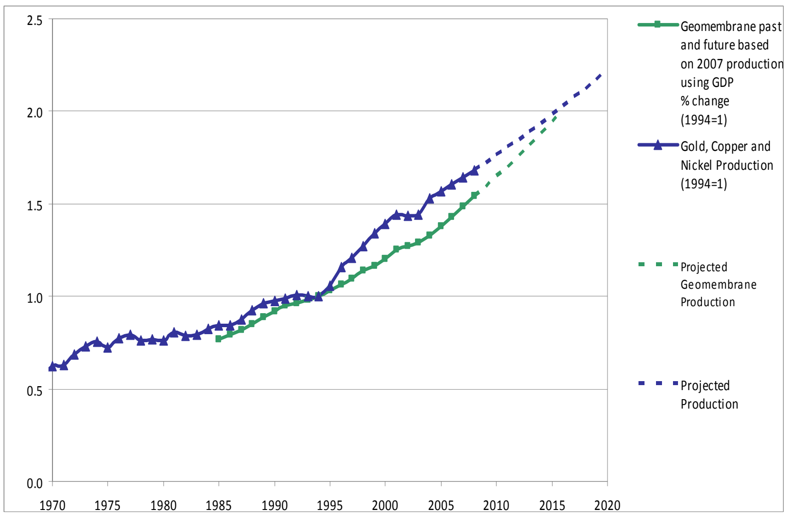
Figure 2: World population, per-capita GDP and Metal Production (normalized), Historic and Projected



2.5 Geomembrane Demand

Considering all uses and the amplifying affect of increasing per capita GDP, geomembrane demand should grow faster than total GDP. That there is a strong correlation between metal production and geomembrane demand (see Figure 3) suggests that both are driven by similar economic factors and are interrelated. Metal production began to have a direct affect on geomembrane demand in about 1985 when gold heap leaching became a significant application, and then both increased after 1992 as copper heap leaching was commercialized. The relationship is expected to continue and to be amplified with increasing use of heap leaching, such as for nickel and uranium, and diversified applications such as tailings disposal and ARD (acid rock drainage) control.

Figure 3: Geomembrane Production and Metal Production (normalized), Historic and Projected



3.0 SUMMARY OF KEY POINTS

Mining is a major application of geosynthetics both in terms of the quantity used and in developing the technologies. Heap leaching has been the largest consumer of geosynthetics in mining, principally geomembranes and related components. The trend is for increased intensity of use within heap leaching, increasing production in traditional areas of copper and gold, and expanding to non-traditional minerals such as nickel and uranium. There is also a strong trend for increasing use outside the heap leaching area, including liners and caps for tailings and waste rock dumps. Simultaneously global demand for minerals should continue to outpace either population or total GDP.

From this, some conclusions can be put forth:

- Population and GDP growth should increase annual geomembrane demand by approximately 45% by 2020 as compared to 2007;
- Increasing per capita GDP suggests increasing per capita geosynthetics demand as higher income levels both drive demand for technology and affords more advanced environmental standards;
- Diversified uses such as waste dump closure, tailings impoundments and ARD control should accelerate demand beyond what historic figures suggest;
- Nickel heap leaching will begin affecting geomembrane demand by 2010, with annual consumption exceeding the equivalent of 1 million square meters at 1.5mm thick.
- Uranium heap leaching could match that of nickel heap leaching;
- Total mining demand is expected to grow fastest in locations such as Brazil, Southeast Asia, Western Australia, and in Africa.

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[ii] Mr. Smith is president of Vector Engineering, Inc. and Vector Panama, S.A. He has nearly 30 years experience in mining with focus on heap leaching and tailings disposal. He resides in Lima, Peru. smith@vectoreng.com.