

Zinc – A Sustainable Metal

Stephen Wilkinson, Eric Van Genderen, Andrew Green, Sabina Grund

Increasingly the zinc industry is being asked to provide information to downstream users of zinc and zinc containing products on the environmental footprint of the materials it produces. Material specifiers and product engineers in key end use markets, such as building, construction and transportation, are more and more interested in selecting materials that have the best environmental profile while meeting traditional cost, quality and technical performance criteria. Understanding the environmental footprint of zinc starts with documenting the resource requirements and environmental releases associated with upstream metal production operations, but it also involves understanding

the impacts and the benefits of using zinc during other stages in the product life cycle. These benefits can arise in use (e.g. extending the life of steel products) and through end-of-life recycling (e.g. by utilizing recycled zinc to create new products). This report represents an overview of the numerous sustainable attributes of zinc and its contributions to a sustainable society.

Keywords:

Zinc – Sustainable Development – Recycling – Millennium goals – Health

Zink – ein nachhaltiges Metall

Immer häufiger wird auch die Zinkindustrie von Weiterverarbeitern von Zink und zinkhaltigen Produkten nach Informationen zum so genannten „Umwelt-Fußabdruck“ gefragt. Konstrukteure und Designer wichtiger Endabnehmermärkte wie z.B. im Bauwesen, in der Konstruktion und im Transportwesen setzen zunehmend vor allem solche Materialien ein, die das beste Umweltprofil nachweisen können und dabei gleichzeitig den klassischen Anforderungen an Kosten, Qualität und technische Eigenschaften entsprechen. Das Verständnis des Umweltfußabdrucks von Zink beginnt mit der Dokumentation der erforderlichen Ressourcen und den Emissionen im Rahmen der nachfolgenden Produktionsschritte zur Metallerzeugung, schließt aber ebenso das Verständnis der Einflüsse und

der Vorteile des Einsatzes von Zink in anderen Stufen des Produkt-Lebenszyklus ein. Diese Vorteile können sich in der Nutzungsphase ergeben (z.B. durch die Verlängerung der Haltbarkeit von Stahlprodukten durch Verzinken als Korrosionsschutz) und durch das Recycling am Ende der Nutzungsphase (z.B. durch die Nutzung recycelten Zinks zur Erzeugung neuer Produkte). Dieser Beitrag gibt deshalb einen Überblick über die zahlreichen Nachhaltigkeitseigenschaften von Zink und über seine Beiträge zu einer nachhaltigen Gesellschaft.

Schlüsselwörter:

Zink – Nachhaltige Entwicklung – Recycling – Jahrtausendziele – Gesundheit

Le zinc – un métal soutenable

El Cinc – un metal sostenible

Paper to be presented as a Plenary Lecture on the occasion of the European Metallurgical Conference EMC 2011, June 26 to 29, 2011, in Düsseldorf, Germany.

1 Introduction

Recognized in India as a metal in 1374, zinc and zinc oxides have been used for centuries for a variety of applications such as making brass to healing wounds. Today we know that zinc is present naturally in rock and soil, air, water and the biosphere, and it is a material that is essential for life for all organisms on the planet, whether they are human, animal or plant. When the supply of plant-available zinc is inadequate, crop yields are reduced, and the quality of crop products is frequently impaired. Dietary zinc deficiency is a

critical problem that affects hundreds of millions of people in many parts of the world.

A very versatile material, zinc also plays a key role in a variety of industrial and product applications. Zinc protects steel from rust – making steel more durable by lasting longer. Less corrosion also means less costs and less environmental impact for maintenance. Zinc sheet applications such as roofing, gutters and downpipes, for instance, can last longer than a lifetime. Like other metals, zinc can be recycled without changing its properties.

These inherent characteristics of zinc – natural, essential, durable, recyclable – make it a desirable material for a range of applications in transportation, infrastructure, consumer products and food production. Zinc's durability and recyclability means that in many applications it can help save natural resources and improve sustainability performance. This report represents a brief overview of the numerous sustainable attributes of zinc and its contributions to a sustainable society.

2 Zinc is durable

One of zinc's most exceptional qualities is its natural capacity to protect steel from corrosion. When left unprotected, steel will corrode in almost any environment. Zinc coatings protect steel by providing a physical barrier as well as cathodic protection for the underlying steel, allowing its service life to be extended indefinitely. Damage caused by corrosion leads to costly and time consuming repairs and has been estimated to cost up to four percent of a country's gross domestic product [1]. By protecting steel from corrosion, zinc performs an invaluable service. It helps to save natural resources by significantly prolonging the life of steel goods and capital investments, such as homes, cars, bridges, port facilities, power lines and water distribution, telecommunications and transport.

The long-term durability provided by galvanizing is achieved at relatively low environmental burden in terms of energy and other globally relevant impacts, especially when compared to the energy value of the steel it is protecting. Numerous studies have shown the high economic and environmental costs associated with repeated maintenance painting of steel structures. These burdens can be significantly reduced by an initial investment in zinc-coated steel. Lack of optimal corrosion protection can leave a damaging economic legacy of repeated maintenance costs. In social housing projects, future maintenance costs will be borne by the local authorities. In public infrastructure projects, use of galvanized steel leads to lower maintenance budgets, releasing public funds for other purposes.

3 Zinc is recyclable

Approximately 60 % of the zinc produced in the USA and Europe originates from mined ores and the remaining 40 % from recycled or secondary zinc. The amount of zinc from secondary sources in developed countries today is limited to about 40 % due to the much lower tonnage of zinc that has been utilized at the time the zinc product e.g. zinc sheet for roofing has been produced – up to 100 years ago. Based on the fact that the use of zinc has been constantly increased during the last century, this amount is expected to increase. In developing regions, the amount of refined zinc originating for secondary materials today can be as low as 10 % [2, 3]. The level of recycling increases each year, in step with progress in zinc production and recycling technology. Product-specific recycling rates are high, such as the recycling rate for zinc sheet that is close to 100 % due to its high metal value. For the zinc and steel industries, recycling of zinc-coated steel provides an important new source of

raw material. Historically, the generation of zinc-rich dusts from steel recycling was a source of loss from the life-cycle (landfill); however, today technologies exist which provide incentive for steel recyclers to minimize waste. Thus, the recycling loop is endless – both zinc and steel can be recycled again and again without any loss of their physical or chemical properties.

Zinc is recycled at all stages of production and use, including scrap that arises during the production of galvanized steel sheet, scrap generated during manufacturing and installation processes and from end-of-life products. The presence of zinc coating on steel does not affect steel's recyclability, and all types of zinc-coated products are recyclable. Similarly, the presence of zinc in alloys does not affect its recyclability; the alloys are remelted and used to manufacture new products of the same alloy.

The amount of zinc available for recycling varies, due to the generally long, useful life of zinc containing products, which is variable and can range from 15-plus years for the zinc-coated steel panels used in cars or household appliances, to over 100 years for zinc sheet used for roofing. Galvanized steel used in public infrastructure applications, such as street lighting columns and transmission towers, are often in service for 50 years or more. All of these products tend to be replaced due to obsolescence, not because the zinc has ceased to protect the underlying steel or building. Recycling of zinc products by the industry also provides an opportunity to help conserve the natural zinc reserves even more.

4 Zinc is essential for human health

Zinc is vital for many biological functions in the human body. The adult body contains two to three grams of zinc, present in all parts of the body, including: organs, tissues, bones, fluids and cells. Zinc is essential for the proper functioning of a large number of proteins and over 100 specific enzymes in the human body [4]. Zinc deficiency in early life can impair physical and neural growth and development, brain function, memory and learning ability. Severe zinc deficiency is characterized by stunting, lack of normal sexual development, poor immune response, skin disorders and anorexia. Further, it is estimated that zinc deficiency is responsible for nearly 450,000 deaths, or 4.4 %, of children under five worldwide (Figure 1 [5]). According to the World Health Organization, zinc deficiency is the fifth leading cause of death and disease in developing nations [6].

The global impacts in terms of human health have been clearly identified by the Copenhagen Consensus (www.copenhagenconsensus.com), a group of eight leading economists, including five Nobel Laureates. In 2008, the consensus stated that, in terms of cost-effective solutions to the world's most pressing problems, providing zinc and vitamin A should be the first priority (out of 40). The group also concluded that zinc and vitamin A could be provided to 80 % of the estimated 140 million undernourished children for \$ 60 million annually, with resulting benefits (in terms of better health, increased future earnings and fewer deaths) of over \$ 1 billion – a return of \$ 17 for each dollar spent.



Fig. 1:
Global zinc deficiency in humans [5]

Because cereals are the principal source of calories, proteins and minerals for many people in areas of the world with widespread zinc deficient soils, they are also the regions with widespread zinc deficiency in humans. In the developing world, cereals provide up to 70 % of caloric intake. For this reason, the zinc content of the major staple foods such as wheat, rice, maize and beans is of particular concern. A study in India has documented lower zinc status (in blood plasma serum) in people feeding on cereal grains with lower zinc content, coming from soils deficient in zinc [7]. Thus, there is a direct and vital linkage between the zinc deficiency in soils, crops and humans in these areas.

5 Zinc is essential for crops

Zinc deficiency in food crops reduces yields and quality, and it lowers the nutritional value of the crops. According to a study by the Food and Agricultural Organization (FAO), an estimated 50 % of the world's agricultural soils devoted to cereal production are deficient in zinc (Figure 2) [8]. Moreover, the study, which examined 190

field trials in 15 countries, found that zinc deficiency occurred in one out of every two trials. Zinc is also widely recognized as the most critical micronutrient deficiency in crops, being one of eight trace elements that plants need for normal growth and reproduction. Although required in small but critical concentrations, zinc plays a vital role in several key functions including: membrane structure, photosynthesis, protein synthesis and defense against drought and disease [5].

Over two-thirds of the rice grown worldwide is produced on flooded paddy soils, which generally contain very low amounts of plant-available zinc. Wheat is typically grown on alkaline, calcareous soils with low organic matter in the semiarid (rainfed) regions of the world. These soil and climatic conditions tend to make zinc less available for uptake and use by plants. Under zinc-deficient soil conditions, plants show a high susceptibility to environmental stress factors such as drought, heat stress and pathogenic infections, which stimulate development of chlorosis and necrosis on the leaves and cause stunted growth.

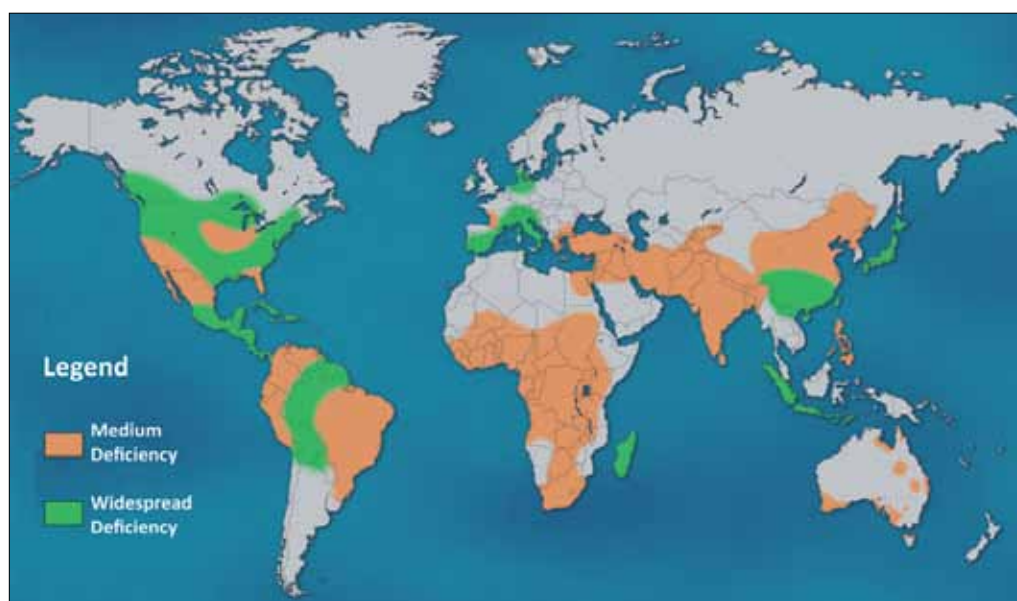


Fig. 2:
Zinc deficiency in world crops [9]

The high prevalence of zinc deficient soils in major agricultural zones severely limits agricultural productivity. Zinc fertilizers can, therefore, make a significant contribution towards goals of higher crop yields in a sustainable and environmentally responsible manner. Simultaneously, zinc fertilizers can enhance grain zinc concentration and thus contribute greatly to daily zinc intake of human populations.

6 Zinc is a sustainable resource

The world is naturally abundant in zinc. It is estimated that the first mile of the earth's crust under land contains 224,000,000 million tonnes of zinc. There are a further 15 million tonnes of zinc in the seabed, and each cubic mile of seawater is estimated to contain one tonne of zinc. Such estimates, however, fail to consider whether or not it is economic, or environmentally acceptable, to exploit these resources. Reserves of zinc – like those of any natural resource – are not a fixed amount stored in nature. Reserves are determined by geology and the interaction of economics, technology and politics. The term “reserves” denotes only what has been mapped and measured today and what can be mined, economically, using current technology. Zinc reserves have increased significantly since the 1950s, as large new ore bodies have been discovered in many areas of the world. The sustainability of zinc ore supplies cannot therefore be judged simply by extrapolating the combined mine life of today's zinc mines (Figure 3).

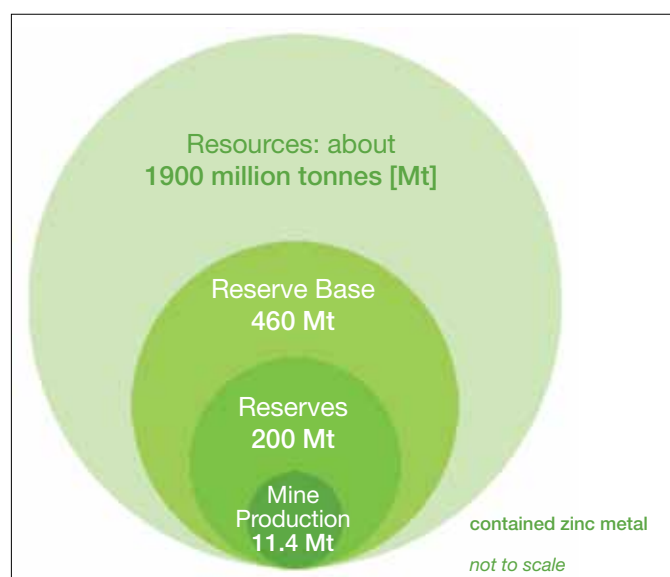


Fig. 3: Schematic relationship between global zinc resources, reserves and production for reference year 2009 [12]

An example of this can be illustrated by comparing United States Geological Survey (USGS) data on zinc reserves. In 1997, USGS reported that world zinc reserves were 140 million tonnes [10], but by 2010, despite 13 additional years of consumption, the USGS reported world zinc reserves of 250 million tonnes [11], a nearly 80 % increase over 1997 levels. During the 1990s, commodity prices were relatively stable at low levels, causing production to stagnate and limiting the creation of exploration and mining operations.

In recent years, prices have become more volatile, with large increases followed by rapid declines. Exploration and production have likewise risen and stabilized or declined. The mining industry is also investing in new technologies and techniques to increase the efficiency of zinc extraction and processing. Recycling of zinc products by the industry also provides an opportunity to help conserve the natural zinc reserves even more.

7 Zinc and Sustainable Development

Increasingly, the mining and metals industry is being asked to provide information to downstream industries on the environmental footprint of the materials it produces. Key end-use markets, such as building and construction, electronics and transport, are becoming more interested in selecting materials that have the best environmental (and social) profile, while meeting traditional cost, quality and technical performance criteria. Understanding the environmental footprint of metals begins with documenting the resource requirements (energy and non-energy) and environmental releases associated with upstream operations (such as mining and refining). But it also involves understanding the impact and, most importantly, the benefits of using metals during other stages in the life cycle of the products of which they are a component.

The global zinc industry is one sector that is working to better quantify the environmental impacts and benefits of production, and to communicate this information to key markets and stakeholders. As a result, the International Zinc Association (IZA) initiated a program to provide scientific information about the sustainability performance of zinc to inform engineers, architects and other individuals involved in the specification of materials. The life cycle assessment (LCA) methodology was chosen because it is the most widely used method for understanding the environmental performance of materials, and it is used by many end-use markets to support material selection and product development. LCA is a decision-making tool used to identify environmental burdens and evaluate the environmental consequences of a material, product, process or service over its life cycle from cradle-to-gate (typical for basic raw materials and commodities) or cradle-to-grave (typical for products and services). LCA has been standardized by the International Organization for Standardization (ISO) and forms the conceptual basis for a number of management approaches and standards that consider the life cycle impacts of product systems (e.g. emerging carbon footprint protocols).

The specific goals of the study were to provide the zinc industry and downstream users of zinc with up-to-date life cycle inventory (LCI) data for primary zinc (ingot at refinery gate; [13]) and primary rolled zinc sheet [14]. The functional units of the study were the production of one tonne of refined metal and/or 1 m² of zinc sheet (super high grade zinc alloyed with copper, aluminum and titanium), respectively. Data coverage represented 32 % of the global zinc production volume (reference year 2005) and more than 50 % of global zinc sheet production (reference

year 2006). The study also looked at five impact categories: primary energy consumption; global warming potential; acidification potential; eutrophication potential, and photochemical oxidant-creation potential.

For primary zinc production, it was found that primary energy demand ranged from 35,000 to 76,000 MJ/t of special high-grade zinc [13]. Variations in the figure were influenced by three main factors: the different characteristics of country-specific power-grid mixes (primary energy demand per kWh of electricity generated); differences in energy efficiency for special high-grade zinc production; and differences at the production sites, with some being more integrated plants producing numerous co-products or, in some cases, zinc is not even the major metal produced. Primary zinc's Global Warming Potential (GWP) was found to be approximately three tonnes of CO₂ equivalent per tonne produced [13]. The analysis of the zinc sheet production process found that primary energy demand was approximately 266.5 MJ/m² and the GWP was approximately 16 kg of CO₂ equivalent per m² [14]. However, the excellent recycling rates of zinc sheet lower the need for primary energy in the circuit. As with any material, the GWP of zinc is best understood in relation to the products in which it is used. For example, zinc's anti-corrosion properties can extend the life of a variety of steel products and reduce their overall impact, therefore making them more sustainable.

In summary, the zinc industry is doing its part to better understand and respond to growing information on the sustainability of its main products. It has also raised awareness among the key stakeholders and will continue to work with other actors in the zinc value chain, to communicate and demonstrate its sustainability benefits. It is clear from these efforts to better understand and quantify the many attributes of zinc (e.g. durability, recyclability, essentiality) that zinc truly is a sustainable material.

References

- [1] KOCH, G.H. et al. (2002): Corrosion Costs and Preventive Strategies in the United States. – U.S. Federal Highway Administration Washington, D.C., USA; 12 pp.
- [2] GRAEDEL, T.E., BERTRAM, M. & RECK, B. (2005): Exploratory Data Analysis of the Multilevel Anthropogenic Zinc Cycle. – *Journal of Industrial Ecology*, 9: 91-108.
- [3] GRAEDEL, T.E. et al. (2005): The Multilevel Cycle of Anthropogenic Zinc. *Journal of Industrial Ecology*, 9: 67-90.
- [4] ANDREINI, C. et al. (2006): Zinc through the Three Domains of Life. – *Journal of Proteome Research*, 5: 3173-3178.
- [5] BLACK, R.E. (2003): Zinc Deficiency, Infectious Disease and Mortality in the Developing World. *Journal of Nutrition*, 133: 1485-1489.
- [6] WHO (2002): The World Health Report. – World Health Organization, Geneva, Switzerland.
- [7] SINGH, M.V. (2009): Micronutrient Nutritional Problems in Soils of India and Improvement for Human and Animal Health. – *Indian Journal of Fertilizers*, 5: 11-26
- [8] SILLANPAA, M. (1982): Micronutrients and the Nutrient Status of Soils: A Global Study. – Food and Agriculture Organization, Rome, Italy.
- [9] ALLOWAY, B.J. (2008): Zinc in Soils and Crop Nutrition. – International Zinc Association, Brussels, Belgium.
- [10] USGS (1997): Mineral Commodity Summaries 1997: Zinc. – U.S. Geological Survey, Reston, Virginia.
- [11] USGS (2011): Mineral Commodity Summaries 2011: Zinc. – U.S. Geological Survey, Reston, Virginia.
- [12] USGS (2010): Mineral Commodity Summaries 2010: Zinc. – U.S. Geological Survey, Reston, Virginia.
- [13] IZA (2010): Zinc Environmental Profile: Life Cycle Assessment. – International Zinc Association, Brussels, Belgium; 8 pp.
- [14] IZA (2010): Zinc Sheet Environmental Profile: Life Cycle Assessment. – International Zinc Association, Brussels, Belgium; 8 pp.

Stephen Wilkinson
Dr. Eric Van Genderen
Dr. Andrew Green
Dr.-Ing. Sabina Grund
International Zinc Association
168 avenue de Tervueren/Box 4
B-1150 Brussels, Belgium