Waste Management Outlook for Mountain Regions

Sources and Solutions

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Executive Summary

Mountains play an essential role in supplying water, energy, food and other services to millions of people living in the mountains and downstream. Ensuring the continued supply of these services has never been more important. However, many mountain regions are experiencing a growing solid waste problem, from ever-expanding urban sprawls and cities, increasing consumption patterns, existing and past mining operations, tourism activities and practices of illegal dumping. Steepness, remoteness, prevailing socio-economic conditions, and vulnerability to natural hazards, makes waste management in mountains more challenging than in lowland areas. Gravity and river flow can also enlarge the footprint of mountain waste to a thousand kilometres or more downstream - and even right into the ocean.

The take-home message is that the inadequate treatment or disposal of waste in mountains not only creates risks for ecosystems and human health in mountain regions, but also for downstream areas. It is truly an issue of global concern. The good news is that there are many options available to prevent and manage waste in mountain environments, in ways that protect mountain ecosystems and people, and prevent problems from migrating downstream. This report highlights both the challenges and the solutions for good waste management in mountain regions.

The Waste Challenges

Mountain communities – challenging conditions for waste management

Many mountain communities in developing countries face significant challenges in managing growing amounts of non-organic waste. Even the more remote communities are faced with more plastics, metals and other non-biodegradable products. Many communities have not developed new practices and norms for managing waste. In many cases, formal institutional systems for waste management are non-existent, resulting in informal means of waste disposal, including open burning and dumping in ravines and rivers – polluting water supply downstream. Achieving economies of scale, for example for the recycling of materials, can be a significant challenge due to the cost and difficulties of transport, and relatively low volumes of recyclable waste. Despite these challenges, some communities have succeeded in implementing various solutions to deal with waste issues in the mountain context.

Mountain tourism – backpacking waste into remote and high places

Tourists on treks and mountaineering expeditions contribute to the increasing volumes of solid waste seen in many of the more remote and higher mountain regions. Where there are no adequate systems in place to collect and manage the waste – particularly in poorer countries and regions – waste is dumped on the side of trails, at camps, or in glacier crevasses. The growth in tourists visiting popular mountain regions, and the accompanying waste issues can be staggering. For example, the Mount Everest region in Nepal has seen an exponential increase in visitors (from 20 in 1964 to approx. 36,000 in 2012). Up to 140,000kg of solid waste is estimated to remain after 60 years of expeditions (Kelliher, 2014). Although well publicised for parts of the Himalayas and Andes, it is a problem that affects almost all mountain regions. Good, preventative measures do exist including bring-your-waste-back policies, camping and national park fees redirected to waste infrastructure, community-based waste initiatives, and successful tourism sector-initiatives. Winter tourism in the mountains, including large, international sporting events such as the winter Olympics, can also have significant waste impacts and implications.

Large mountain cities – same challenges as lowland cities, and a few more

Several large mountain cities with populations of close to a million or more inhabitants exist in Africa, Asia and Latin America. The types and characteristics of solid waste in these cities, and the way that waste is managed, is more related to the level of development of their countries, rather than their altitude. A common trait is insufficient or poor waste management: collection rates are typically low (30 – 60 percent in low income countries, and from 50 to 80 percent in middle income countries (Scheinberg, Wilson and Rodic-Wiersma, 2010), mixed waste collection occurs without separation at source. In some mountain cities, waste is disposed of in open dumpsites as opposed to sanitary landfills. While open dumping is by no means unique to mountain regions, mountain environments pose additional risks, if these sites are located near to watercourses, with the potential to pollute water that is used by large populations downstream. In spite of these challenges, many mountain cities have good experiences in managing solid waste due to the national policies and legal frameworks implemented in the countries to which these cities belong. This includes for the recycling of inorganics, composting of organics, private sector involvement, social inclusion of informal recyclers, management of E-wastes, and construction of sanitary landfills.

Globally, municipal solid waste is expected to double by 2025 (Hoornweg & Bhada-Tata, 2012), creating a huge demand for urban public services, including within mountain cities. Growth in mountain cities is also expanding to hazard-prone areas such as alongside riverbanks and steep hillsides, often resulting in the development of informal settlements that are highly vulnerable to natural hazards and disasters. Disasters themselves carry significant waste implications, generating huge amounts of waste in a short period of time.

Mining at altitude – a mountain of waste that creates risks far downstream

Mining is the most common heavy industry within mountainous regions of developing countries. Artisanal and small-scale mining are also common. Both carry with them significant waste implications. In mountains, steep slopes, terrain instability, seismic activity and adverse weather conditions add another level of complexity and risk to mine safety and waste management. In particular, mine tailings and their long-term storage at mountain mines requires urgent attention: some of the largest mines in the world, and consequently some of the largest waste dumps, are found in mountain regions. Statistically speaking, some of these storage dams are likely to fail in the future (Morgenstern et al. 2015). Poorly managed waste in mountain regions has the potential to move downwards, expanding the waste footprint of even a small mountain mine. Contaminants can be found more than 1000 km downstream from a mountain mine, such as is the case for the large Ok Tedi mine in Papua New Guinea, which has affected the livelihoods of over 30,000 people, decreased fish stocks and caused extensive degradation of forests. More intense rainfall and flooding events have the potential to increase the risks of tailings storage failure and weaken existing waste infrastructure.

At the global level, there is very little information on the extent of waste crime in mountain regions. However, the remoteness of mountain regions is likely to make them easy targets for waste crimes, and certain cases point to this. Of particular concern in the mountain context are mining activities, which produce large amounts of waste, some of which can be hazardous with the potential to have large downstream impacts. Illegal mining activities may involve breaching environmental and safety regulations for existing activities, or neglecting risks from previous operations.

Impacts of upstream waste on freshwater ecosystems – a growing issue deserving research and attention

One of the main ways in which mountains are linked to lower-lying areas is through rivers. These rivers bring much needed water, but also carry plastic pollution downstream. There has been much attention in recent years on plastic pollution in the marine environment, but considerably fewer studies have so far studied the impact on freshwater environments. This is an area that deserves further attention.

Recommendations: *The Waste Solutions*

New knowledge for informed decision-making and implementation of solutions

Implement waste monitoring programmes. Monitoring schemes are needed to establish a baseline against which actions can be measured, and to assist in developing a systematic overview of the problems and their causes. In popular mountain tourist areas, data on visitor numbers, length of stay and activities, combined with the experience and observations of local communities, are important for managing and anticipating waste removal and disposal requirements. Risk assessments of waste management in mountain areas are also needed. This includes the potential risk for downstream areas from both large and small-scale dumping (whether legal or illegal) and industrial waste.

Fund scientific research. Research is needed to better understand the relationship between different waste streams and their biophysical impacts on sensitive mountain environments, on the health of mountain communities, and on the linkages between upstream and downstream areas. An international research agenda on mountain waste issues should be considered, taking an integrated approach involving both mountain and downstream scientific networks. The waste implications of sectors such as forestry and agriculture, which have not been addressed in this report, should also be included in future research initiatives.

Applied and participatory research is needed to better understand existing public attitudes to waste and how to best incite behavioural change and adoption of sound waste management practices in challenging environments and socio-economic conditions.

Capacity building and awareness raising

Build awareness at all levels of the large potential downstream impacts and global nature of certain waste streams in mountain environments, and the threats posed to human health. The focus should be on people living in mountain communities and those who visit mountains on a temporary basis, such as tourists. This should start with promoting sustainable consumption through the 3Rs: reduce, reuse and recycle. Awareness raising should also talk about risks to public health of inappropriate disposal and treatment of waste and appropriate and economic alternatives. Open burning of non-biodegradable waste should be strongly discouraged or even banned. A preventative approach is needed to make sure that sustainable waste management practices are introduced before waste problems become too severe.

Prevent waste disposal in mountain areas wherever possible. A combination of both education and awareness raising to promote waste-reduction or waste-eliminating behaviour, and smart policies and instruments, are needed. This is particularly needed in mountain areas, as the costs of waste collection and removal are increased by remoteness, rugged terrain and poor infrastructure.

Build the capacity of mountain communities, and both small and large municipalities to plan for sound management of waste. Integrated management plans and approaches to waste management are needed that include avoidance/prevention (including with regards to illegal dumping), recycling, minimisation, treatment and disposal. Promoting local capacity and use of local knowledge is important to ensure measures are appropriate for local conditions.

Develop small-scale solutions that are adapted to more remote mountain settings. Options include promoting community-based, alternative options to landfills for organic wastes and waste collection centres to promote the collection and sorting of non-organic recyclables. Communities should consider working together to create shared collection centres in order to accumulate a greater volume of recyclables that can then be sold. New landfills should be sited in areas that minimise the potential for runoff that can contaminate important water sources. Existing landfills that pose risks should be relocated where possible for the same reasons. Following the waste hierarchy where waste cannot be reused or recycled due to technical, economic or environmental limitations, systems that convert municipal waste to energy (WtE) should also be explored particularly in more populated areas, as alternatives to or as means of reducing waste to landfilling. This can also lead to reduced greenhouse gas (GHG) and short lived climate pollutants (SLCPs) emissions, therefore contributing to climate change mitigation opportunities. Technological innovation research should be also be supported to explore new methods applicable to mountain settings, e.g. for waste to energy, and composting.

Ensure that the tourism industry – and tourists – are educated on waste issues, and contribute to the financing and management of waste solutions in mountains. In line with the polluter pays principle, the mountain tourism industry and tourists themselves should bear responsibility for financing the management of the waste created in the areas they visit. Waste management practices should be integrated in the tourism industry, such as bring-back-your-waste policies and re-directing fees (e.g. entry fees, camping fees) into waste management operations. Dialogue and partnerships between tourism operators and local communities should be encouraged. Tools such as sustainable tourism eco-labels and guidelines should be considered for the mountain context, to drive innovation and best practices on reducing waste and greening the tourism sector in mountains.

Promote education on waste management within the mountaineering community. The mountaineering community's global governing bodies, such as the International Climbing and Mountaineering Federation (UIAA) and the International Federation of Mountain Guide Associations (IFMGA), as well as national mountaineering organizations should revise current procedures, guidelines, training and certification practices to integrate and instil environmental values, including sensitization of the consequences of waste and its management. The mountaineering community should also actively engage in the broader policy and management discussions to bring the voices and experiences of mountaineers to the decision-making table.

Strengthen policies, enforcement capacities and monitoring for high-risk sectors in mountains

Promote national and global dialogues across sectors such as environment, tourism, industry, and defence, involving government, the private sector and civil society to promote understanding of challenges, risks and opportunities for waste management in mountain regions, and to reduce potential conflict across national borders. Information exchange and knowledge platforms should also be considered to share best practices.

Strengthen national legislation, enforcement capability and monitoring of the mining sector and the management of mining waste. This includes strengthening environmental standards and targets, and ensuring that the responsible law enforcement authorities have the required skills and resources to perform their duties so that mining projects proceed in accordance with the law. Ensuring transparency and access to information is necessary for monitoring and creating incentives for all stakeholders to play by the rules, and should be part of the mining licensing permit condition. Remediation plans should also form part of any license, and a security fund should be established at each mine site large enough to cover the estimated environmental liabilities upon closure and remediation.

Ensure private sector responsibility. Private contractors and companies, whether it be in tourism, mining, construction or other sectors, should be made responsible for managing the wastes generated through their activities. Enforcement should be ensured through legal contracts. Corporate social responsibility should also be encouraged.

Strengthen and protect civil society organisations' ability to monitor compliance in mining and other sectors. Civil society has a strong role to play in ensuring that mining companies "play by the rules" and follow adequate standards for environmental stewardship. These organisations also have an important role in fighting corruption and illegal activity, and monitoring of public procurement and service delivery (e.g. municipal waste services).

Increase the capacity of artisanal and small-scale miners to reduce their environmental and health effects. Alternative technique to the use of mercury and cyanide exist, such as gravity methods. The awareness and capacities of artisanal miners should be increased to apply such methods.

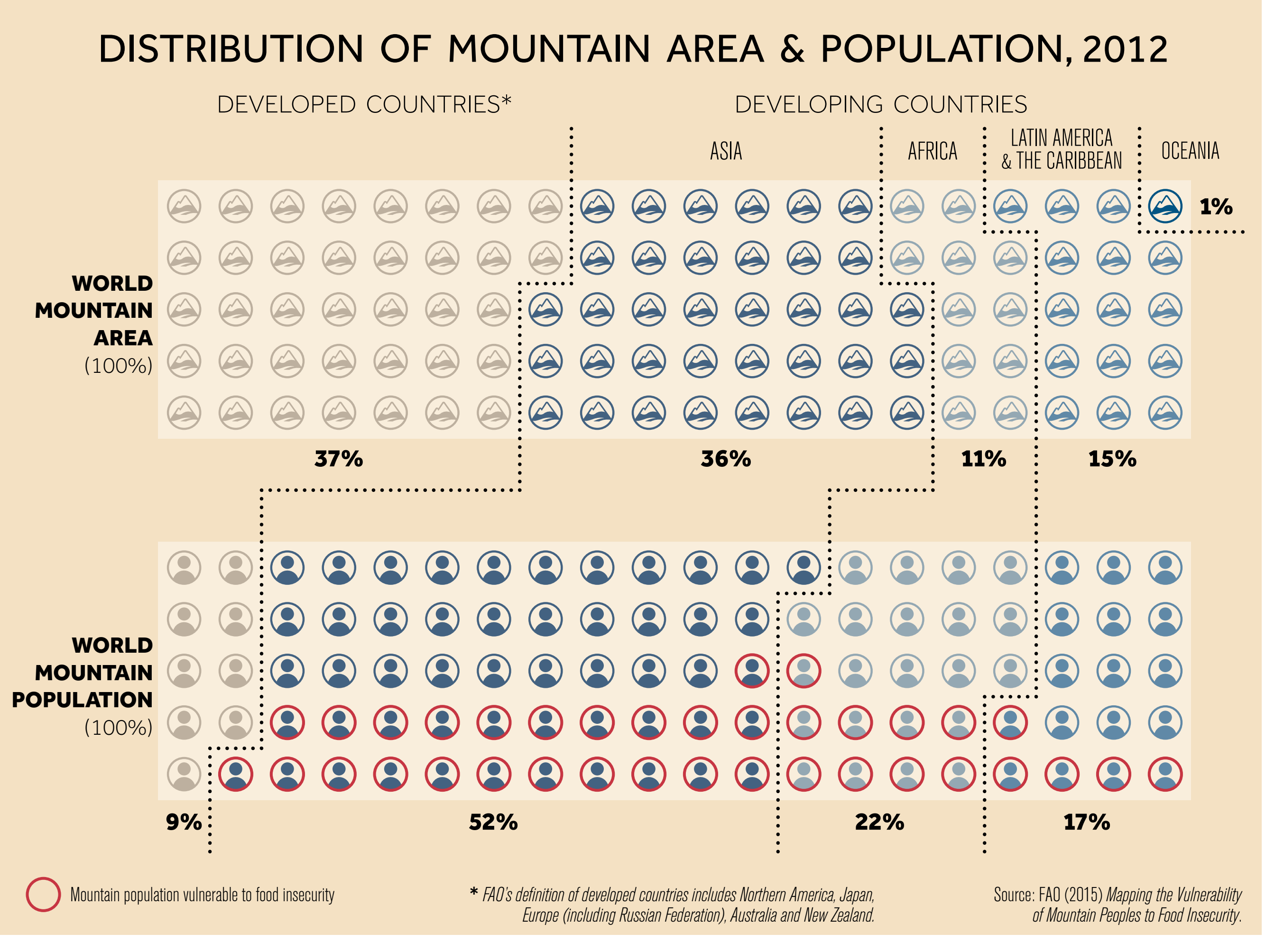
Prepare disaster waste management plans for areas with a high exposure to natural disasters. Mountain areas are particularly vulnerable to earthquakes, landslides and floods which can cause immense amounts of waste. Immediate waste management is needed to facilitate rescue efforts and also to reduce the spread of disease and environmental impact. Disaster waste management plans should be prepared before they are needed to facilitate effective use of scarce resources both during and after extreme events.

Introduction

The Waste Management Outlook for Mountain Regions provides an analysis of waste issues pertinent to the world's mountains, with an emphasis on low and middle-income countries. It complements the Global Waste Management Outlook (GWMO, 2015), which provided a comprehensive global overview of the state of waste management around the world in the 21st century.

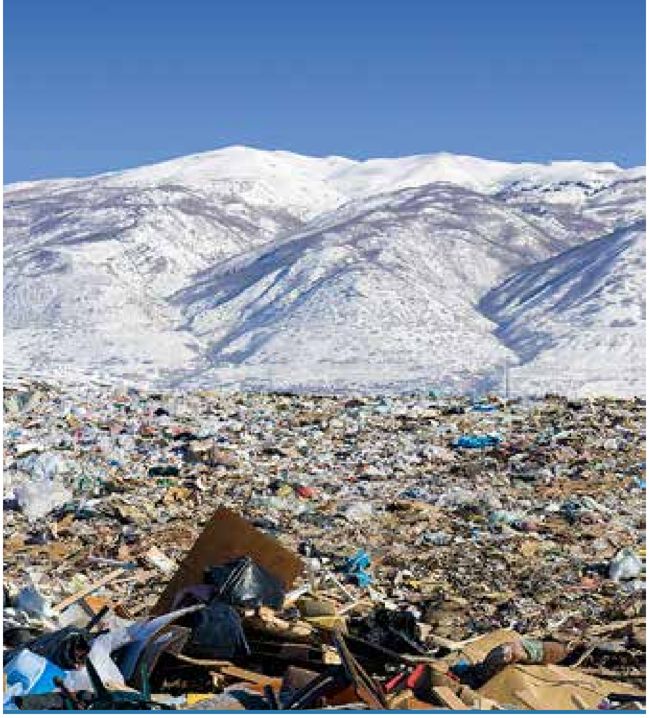
The intention of the Waste Management Outlook for Mountain Regions is to highlight the most important waste management challenges and solutions that are specific to mountains, and their downstream implications. These are grouped according to the sources of waste: remote mountain communities, mountainous cities and larger urban areas, tourism and mining. Issues such as waste crime, plastic pollution, and the linkages between exposure to natural hazards, disasters and waste are also included. The latter three are labelled as "emerging issues" due to their increasing importance, but which happen to be relatively poorly studied and require further attention. It is important to mention that this report does not seek to be fully comprehensive. Several waste-relevant issues, including military activities, as well as those related to forestry and agriculture in mountainous regions, are not covered in this report but certainly deserve specific attention.

This report has benefited from a wide range of input and oversight. An advisory board was established to oversee the process, which included UN Environment (UNEP) and its International Environmental Technology Centre (UNEP IETC), the International Solid Waste Association (ISWA), regional mountain organisations such as ICIMOD, national ministries, and individuals with



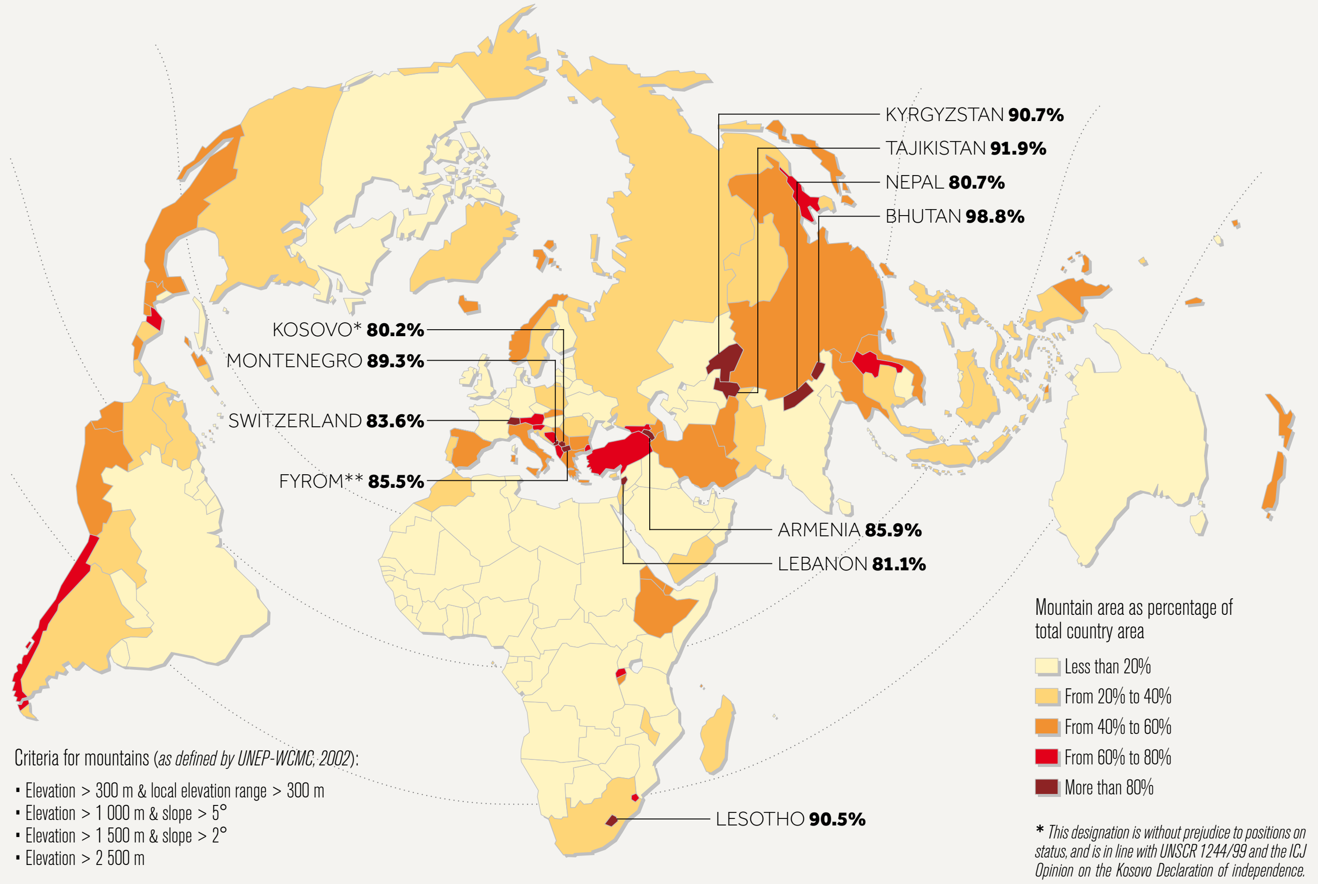
significant experience in either mountain environments, waste issues or both. A stakeholder consultation meeting, entitled "Waste(ing) Mountains", was organised at the World Mountain Forum in Mbale, Uganda in October 2016 during which a draft of the report was presented. Feedback was received from participants of various mountain regions around the world.

The Waste Management Outlook for Mountain Regions is targeted at local and national governments of mountainous countries, local communities, the private sector, civil society and the international research community who work in mountain areas and have an interest or mandate in improving waste management. Given the global dimension of some of the waste issues in mountains, this Outlook is equally relevant for downstream countries and communities. It will also be of interest to individuals who visit mountains for recreation, such as trekkers, mountaineers and other tourists.



Landfill in the Wasatch Mountains. *Photo © iStock/avid_creative*

PERCENTAGE OF MOUNTAIN AREA PER COUNTRY



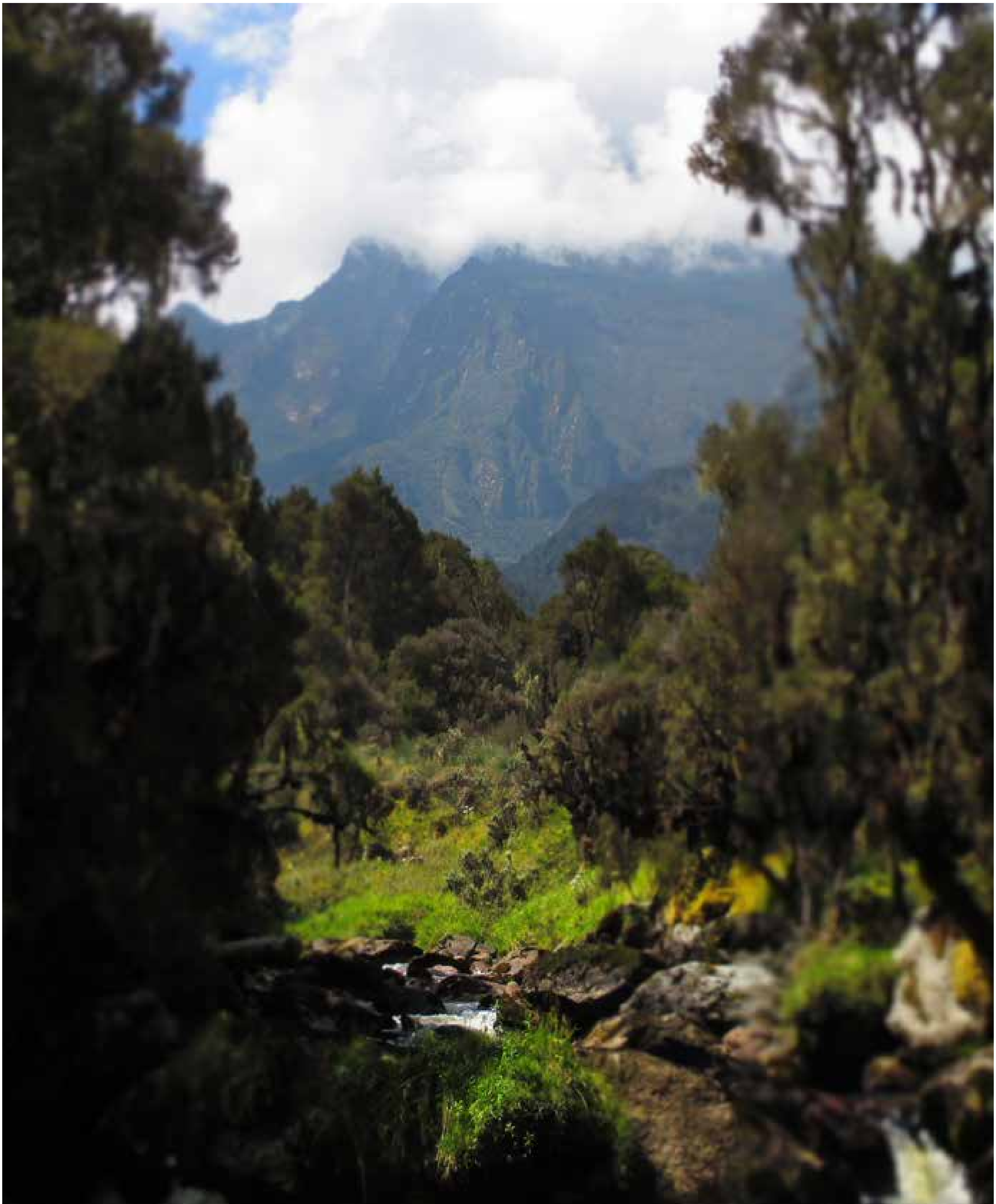
Criteria for mountains (*as defined by UNEP-WCMC, 2002*):

- Elevation > 300 m & local elevation range > 300 m
- Elevation > 1 000 m & slope > 5°
- Elevation > 1 500 m & slope > 2°
- Elevation > 2 500 m

** This designation is without prejudice to positions on status, and is in line with UNSCR 1244/99 and the ICJ Opinion on the Kosovo Declaration of independence.*

*** Former Yugoslav Republic of Macedonia*

Source: Analysis by GRID-Arendal, 2016. Mountains derived from US Geological Survey National Mapping Division, EROS Data Center (EDC) (1996) GTOPO30.


The Ruwenzori Mountains, Uganda. *Photo © Kristoffer Alfthan*

Sources of Waste and Solutions

Remote Mountain Communities

Mountain Cities and Urban Centres

Financing Solid Waste Management in Communities and Cities

Adventure Tourism and Recreation: Mountaineering and Trekking

Mining at Altitude

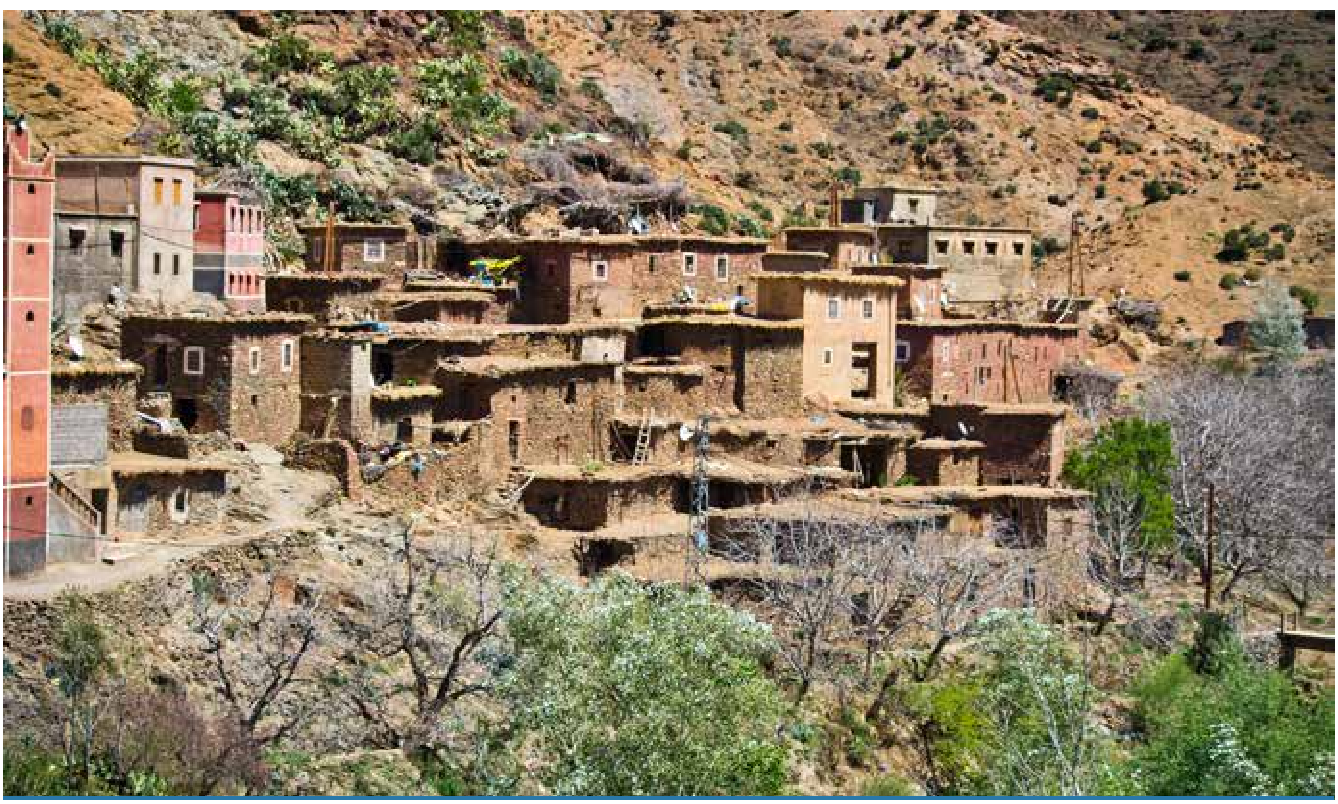
Remote Mountain Communities

Many of the general problems of solid waste management (SWM) in mountainous regions – such as the difficulty of transporting waste and finding suitable landfill sites – are amplified in small and remote mountain communities. In developing countries, formal institutional systems for SWM in remote mountainous regions are largely non-existent. In tourist destinations, waste produced in small mountain communities is inextricably linked to the tourism industry.

Small and remote communities need to have local, community-based strategies to deal with waste effectively. Waste management should focus more on improved separation of waste at source, reusing and recycling waste, and disposing of the remaining waste in an environmentally sound manner – composting the organic matter and storing the non-biodegradable material in collection facilities. Care should also be taken to dispose of health care waste in a safe manner.

Composition of waste and volumes

The composition and generation of waste varies across localities and is dependent on many factors such as local consumption patterns, eating habits, income levels and time of the year. However, there are a few general trends. First, the share of organic and biodegradable waste tends to be higher in rural mountain regions than in urban areas. Second, the proportion of organic waste has decreased over the past decade due to an increase in packaging. This relates to general global trends in consumption patterns as well as an increase in mountain tourism (Gidarakos, Havas and Ntzamilis, 2006). Third, the total amount of solid waste produced correlates positively with income (Modak, Wilson and Velis, 2015a).



A village in the Atlas Mountains, Morocco. *Photo © iStock/CCat82*

Lukla, a small town which is popular starting point for treks into the Everest region of Nepal. Photo © iStock/efesenko

Organic and biodegradable material forms the highest proportion of waste generated in rural/remote communities globally (Taboada-González et al., 2010; ADB, 2013; Allison, 2008). Organic waste is waste that degrades naturally within a few weeks or months. This includes leftover food, fruit, vegetables, beverages, plant residues, seeds, paper and ash from firewood. Non-biodegradable waste, on the other hand, persists in the environment for decades or even hundreds of years and includes materials such as plastics, glass bottles, metal tins, processed leather and e-waste. Tourists often bring products and materials with them – for instance, modern plastics and electronics – which are relatively scarce in remote mountain regions.

While the organic/biodegradable waste is relatively harmless from an environmental perspective, the non-biodegradable waste poses substantial risks, especially when disposed of improperly or burned, causing air and water pollution, and posing risks to domestic animals and wildlife. Plastics which are labelled as biodegradable can also persist for long period in the environment (UNEP and GRID-Arendal, 2016).

Tourism, remote communities and waste

Tourism is important for many developing economies (World Tourism Organization, 2016). The steady growth in the industry has meant that the numbers of visitors to mountainous regions has also risen, drawn by the natural surroundings, the lure of adventure and the cultural opportunities that mountains offer. Mountain tourism provides one of the few opportunities to develop poor mountainous regions. According to UNEP (2007), travel to mountain regions is thought to account for between 15 and 20 per cent of global tourism – although this is a very rough estimate. Some mountain areas receive far more tourists than others: the European Alps, the North American Rockies and Japan typically receive tens of millions of tourists each year (Debarbieux et al., 2014). Mountain tourism has also seen a steady growth in recent years in individual countries. For example, from 2000 to 2010 tourism was the fastest growing sector of the Peruvian economy (Larson and Poudyal, 2012). In the Caucasus, tourism represents a major part of the Georgian economy and a significant increase is forecast in its mountainous areas (World Travel and Tourism Council, 2015).

Mountain tourism includes activities such as trekking and hiking, climbing or skiing; and in some countries, visiting pilgrimage, heritage and historical sites. Day trips to mountainous areas are also common. In many cases, these activities are closely linked to small and remote mountain communities. Consequently, the volume and composition of waste being generated in these communities is often determined by the activities and practices of businesses in the tourist industry, as well as the behaviour of tourists themselves (Manfredi et al., 2010; Allison, 2008; Kuniyal, 2005a; Byers, 2014). During the peak tourist season the amount of waste is sometimes twice as much as the amount generated during the rest of the year (Manfredi et al., 2010). For example, in the Sagarmatha National Park and Buffer Zone in the Nepalese Himalayas, waste generation ranges from 4.6 tons per day during the peak season to 2 tons per day at other times of the year. In many small mountain communities waste is inextricably tied to tourism; any serious waste management solution must therefore involve the tourism industry (Manfredi et al., 2010).

Systems of waste management in small and remote mountain communities

Small and remote mountain communities face very specific challenges to waste management. Poverty is generally more widespread in mountain regions than in lowland areas (FAO, 2007). Many mountain communities have multiple, pressing concerns, such as economic development and food security, and as a result waste management is not given as much importance (Wilson, 2007). In mountain areas in developing countries, 39 per cent of people are food insecure, compared to an average of 12.5 per cent in lowland areas (FAO, 2015).

There is little data on the management of waste in small and remote mountain communities. The few studies available suggest that formal institutional systems for SWM in remote mountainous regions in developing countries are largely non-existent. A study of waste disposal sites in use in 2012 in Nepalese municipalities found that less than half of the waste in these areas was collected (Shakya and Taladhar, 2014). One study which focused on waste management across hill stations, trails and expedition sites in the Indian Himalayas, found that the relevant authorities, (such as local municipalities) had no adequate sites, infrastructure or funds to dispose of the waste generated by visitors. The study also found that most trekking and expedition areas were outside municipal boundaries and waste management was entirely

Open dumping on a mountain side in Gangotri (Uttarkhand, India).
Photo © Aditi Ramola

Overflowing waste containers in Uttarkashi (Uttarakhand, India).
Photo © Aditi Ramola

dependent on local people and visitors (Kuniyal, 2005a). Similar findings are reported in Nepal (Kuniyal, 2005b).

In more developed countries, mountain communities can also be disproportionally underdeveloped and struggle with waste management. In the Romanian Carpathians, for example, waste is often dumped on flood plains (Mihai et al., 2012). Armenia – a lower middle-income, mountainous country – has several communities that are geographically separated from the main urban areas, where the current approach to waste management involves simple 'truck and dump technology'. There is an absence of both institutional capacity and technical parameters for SWM and a lack of general awareness of waste management issues within small and remote mountain communities (ADB, 2015).

A common problem in the disposal of waste in mountainous regions is the difficulty in transporting waste from the point of generation to landfills, and sorting and recycling facilities (Chen, 2010). In hilly terrain, roads meander along circuitous routes to avoid steep gradients and impassable rock formations. This increases the distance that waste vehicles must typically travel to transport the waste to its destination. Furthermore, the differences in elevation mean that vehicles must use more fuel to cover a given distance (Asian Development Bank, 2013). Thus, the costs associated with waste collection and disposal in mountain regions can be significantly higher than in other areas.

In Nepal, the vehicles and equipment available for waste collection and transport in each municipality varies widely and can include rickshaws and carts for primary collection, tractors for secondary collection or transport, and dump trucks for transport to the disposal sites (Asian Development Bank, 2013). In some of the most remote communities, there are simply no roads (Kuniyal, 2005b). In remote mountain areas, transportation may include the use of animals such as yaks, llamas, horses, donkeys and mules (Worboys et al., 2015).

In contrast to urban areas, formal waste management sectors often do not exist in smaller towns and more remote settlements in the mountains. Generally, the volumes of waste generated in these regions are much smaller than in larger urban areas and tend to be dominated by organic waste. For instance, studies show that in Nepal up to 70 per cent of municipal solid waste consists of organic material (Pokhrel and Viraraghavan, 2005; Dangi et al., 2011). The quantities of non-organic recyclable waste generated in mountainous regions in the developing countries are too small to make recycling an economically viable enterprise.

In the absence of formal waste management systems, there are a variety of informal approaches to waste collection, sorting, recycling and disposal. Non-biodegradable waste in some communities in Himachal Pradesh (Indian Himalayas) is collected by waste pickers, who either sell it as raw material to recyclers or reuse the waste themselves (Kuniyal, 2005a). In other areas in the Himalayas, local governments advise the local population to burn their rubbish in household rubbish pits (Allison, 2008). The same study found that villagers dispose of items that they cannot burn or are too big for garbage pits (such as household appliances), by throwing them into ravines.

Rubbish bin in Nepal. Photo © Björn Alfthan

Rural mountain development projects and waste side-effects

Development projects often fail to address predictable changes in waste generation. For instance, the provision of electricity to mountain communities is often accompanied by an increase in waste that is often difficult to safely dispose of. While bringing important improvements – lighting without the need for indoor fires, for example – these projects also create a need to manage new kinds of waste such as small appliances and light bulbs. An electrification project in Bhutan, for example, provided electricity and lighting to highland communities. However, the light tubes did not come with instructions for disposal and there was no system of hazardous waste management in place. As a result, people were exposed to hazardous materials such as mercury (Allison, 2008).

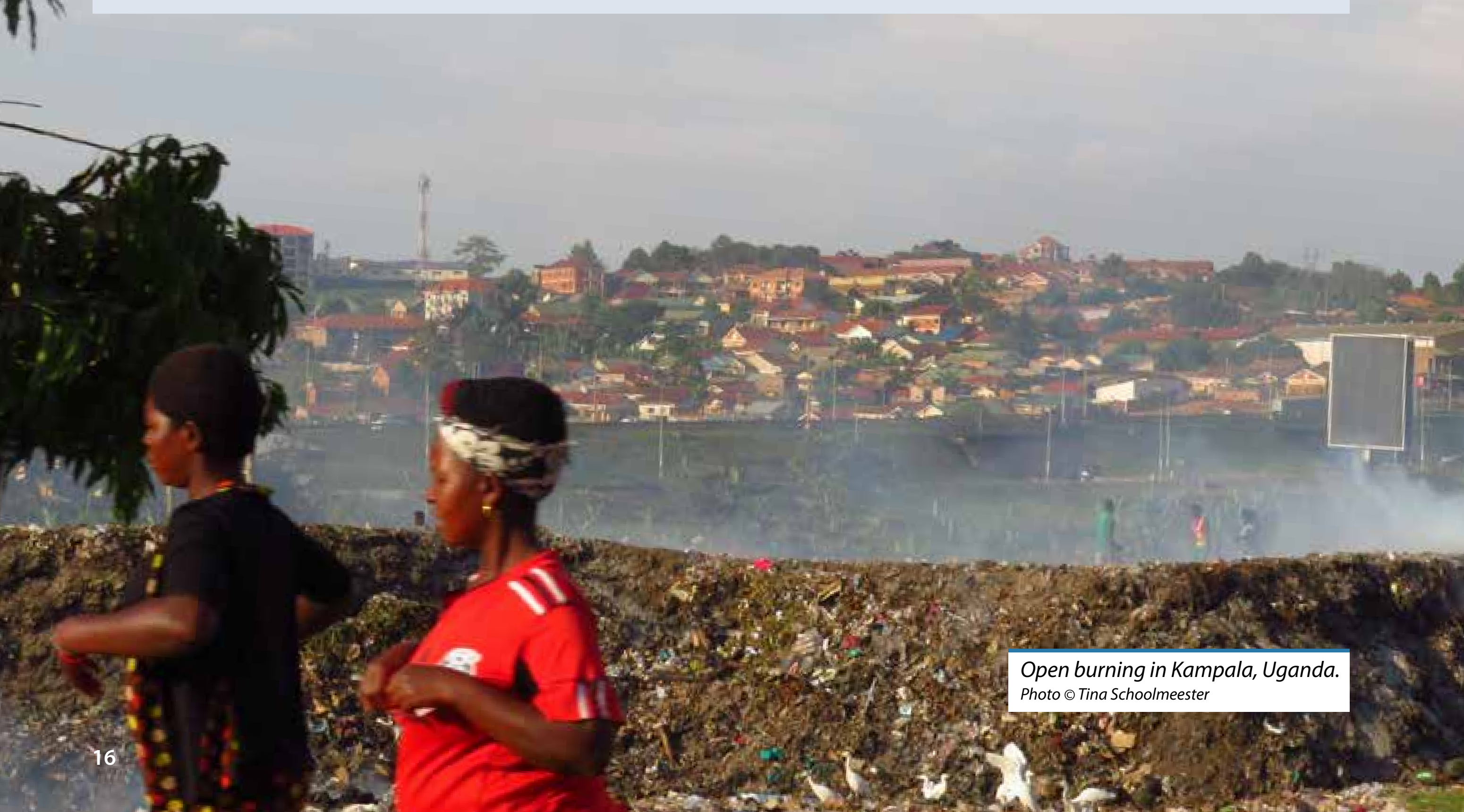
Open burning of domestic waste

The open burning of waste is a major source of air pollutants and particulate matter emissions in developing countries (Wiedinmyer, Yokelson and Gullett, 2014). Studies suggest that as much as 29 per cent of global anthropogenic emissions of small particulate matter (tiny solid particles and liquid droplets from dust and metals that can penetrate deep into the lungs) come from trash fires; and about 10 per cent of mercury emissions and 40 per cent of polycyclic aromatic hydrocarbons come from open burning (UNEP, 2013). Along with a variety of health impacts such as respiratory disease, cardiovascular disease and cancer, the open burning of waste also emits greenhouse gases and Short Lived Climate Pollutants (SLCPs)[1] such as black carbon into the atmosphere, exacerbating the impacts of climate change. Alarmingly, estimates suggest that up to 40 per cent of the world's waste is dealt with in this way (Thompson, 2014; Wiedinmyer, Yokelson and Gullett, 2014; Nagpure, Ramaswami and Russell, 2015).

Several reports on waste management in mountainous regions across the world suggest that open burning is one of the ways in which remote mountain communities manage their waste. For instance, a study in the Hinku Valley region in Nepal reported that tin cans, aluminium beer cans, glass bottles, plastic bottles and other plastic goods are "burned and deposited in landfills located outside of villages. Local lodge owners refer to these accumulations by the misnomer 'burnable garbage', which is indeed burned periodically with little effect prior to being covered with soil." (Byers, 2014).

In Bhutan, local government health workers advise villagers to "burn their garbage in household garbage pits" (Allison, 2008). A 2010 study (Manfredi et al., 2010) conducted in the Sagarmatha National Park and Buffer Zone in Nepal reported that "half of the plastic accumulated in the region is openly burned", while 40 per cent is dumped in pits or scattered; only a small amount of plastic is reused by locals. Other non-biodegradable items are also often buried, burned or left on the ground.

Open burning of waste produces black carbon, an aerosol that can absorb solar radiation (light), reduce albedo (reflectivity) when deposited in snow and ice, and interact with clouds. Through these mechanisms, black carbon has been linked to a number of climate impacts, including increased temperatures and accelerated ice and snow melt (EPA, 2016). Black carbon is thought to play a considerable role in the melting of mid-latitude glaciers (Li et al. 2016). Exposure to black carbon can also lead to a number of health defects including lung cancer and strokes (Crump et al., 2016).



Open burning in Kampala, Uganda.
Photo © Tina Schoolmeester

Options for waste management

Where formal waste management systems do not exist, small and remote communities need to have community-based local strategies to deal with waste effectively. The treatment of organic waste – which makes up a large proportion of waste generated in these communities – can lead to significant reduction in waste volumes.

However, typical waste management solutions, such as sanitary landfills and mechanical biological treatment plants, are often not viable due to the topography of mountain regions and the economic constraints – the levels of funding and the volumes of waste generated are not large enough to warrant such facilities. Transportation costs are prohibitively high and the resources to construct and maintain modern treatment plants are not available. In such cases, innovative micro-level biocomposting in shallow pits could be a feasible method for treating the organic waste, thereby reducing waste volumes and helping to alleviate the environmental pollution caused by the improper management of waste in remote regions (Li et al., 2011; Kuniyal, 2005b).

Depending on weather conditions, composting can be carried out either in pits outside or under a roof. In dry regions, the compost must be adequately moistened and in wet regions it has to be protected from too much moisture, particularly during the monsoon/rainy season. Depending on the quality of the compost generated from this process, it could either be left in the pits or be used locally for farming. However, at very high altitudes, extreme temperatures, and a lack of oxygen and atmospheric pressure limit the effectiveness of traditional composting methods.

With the growing influx of tourists into mountain regions the composition of waste in many remote regions is changing and the proportion of plastics, glass, metal and e-waste is increasing. This non-biodegradable waste can remain in the environment for a very long time and poses substantial risks, especially when improperly disposed of or burned, causing air and water pollution (UNEP, 2007; Kuniyal, 2005a).

Raising community awareness of the economic value of non-biodegradable waste and promoting behavioural change would help develop effective waste management and prevent the build-up of materials on mountain slopes. According to Byers (2014), “programmes that build awareness, provide training and test incentives for lodge owners to recycle and/or remove solid waste from the high-altitude environment … are urgently needed”. Such incentives include placing an economic value on recyclables – for example, paying a deposit on containers would encourage consumers to recycle them and get some money back after use.

Local solutions for a global problem

While SWM is a global problem, specific local waste management strategies are needed to effectively meet this universal challenge. Waste management strategies and policy instruments that are not based on a profound understanding of local conditions are bound to fail. This is illustrated by instances from both the developing and developed world of well-meaning governments and organizations adopting waste management solutions that ended in failure and significant economic loss because crucial local conditions or specificities were overlooked. For example, in the city of Lucknow in India, a costly anaerobic digestion plant (USD 15 million) had to be shut down because of a lack of ‘acceptable’ organic waste (Rodic, 2015c).

Despite the odds, some communities in remote mountain regions have succeeded in putting in place effective modern SWM systems. The key to their success is the reliance on technologies and equipment adapted for local use. The case of the remote city of Ghorahi in Nepal, illustrates how much can be achieved with limited local resources, provided careful and intelligent planning is used. Ghorahi has a well-managed plant that includes facilities for waste sorting and recycling; a sanitary landfill that is buffered from the surrounding area by forests, gardens and a bee farm; and a leachate collection and treatment centre (Scheinberg, Wilson and Rodic-Wiersma, 2010). The main reason for the success of waste governance in Ghorahi was a “clear vision and strong determination”, which enabled the municipality to “use a small initial investment from the municipality budget to mobilize national financial support and to bring the site into operation within five years”. Another factor contributing to their success was a “strong landfill management committee involving local people and key stakeholders to ensure that the site is properly managed and monitored” (Scheinberg, Wilson and Rodic-Wiersma, 2010).

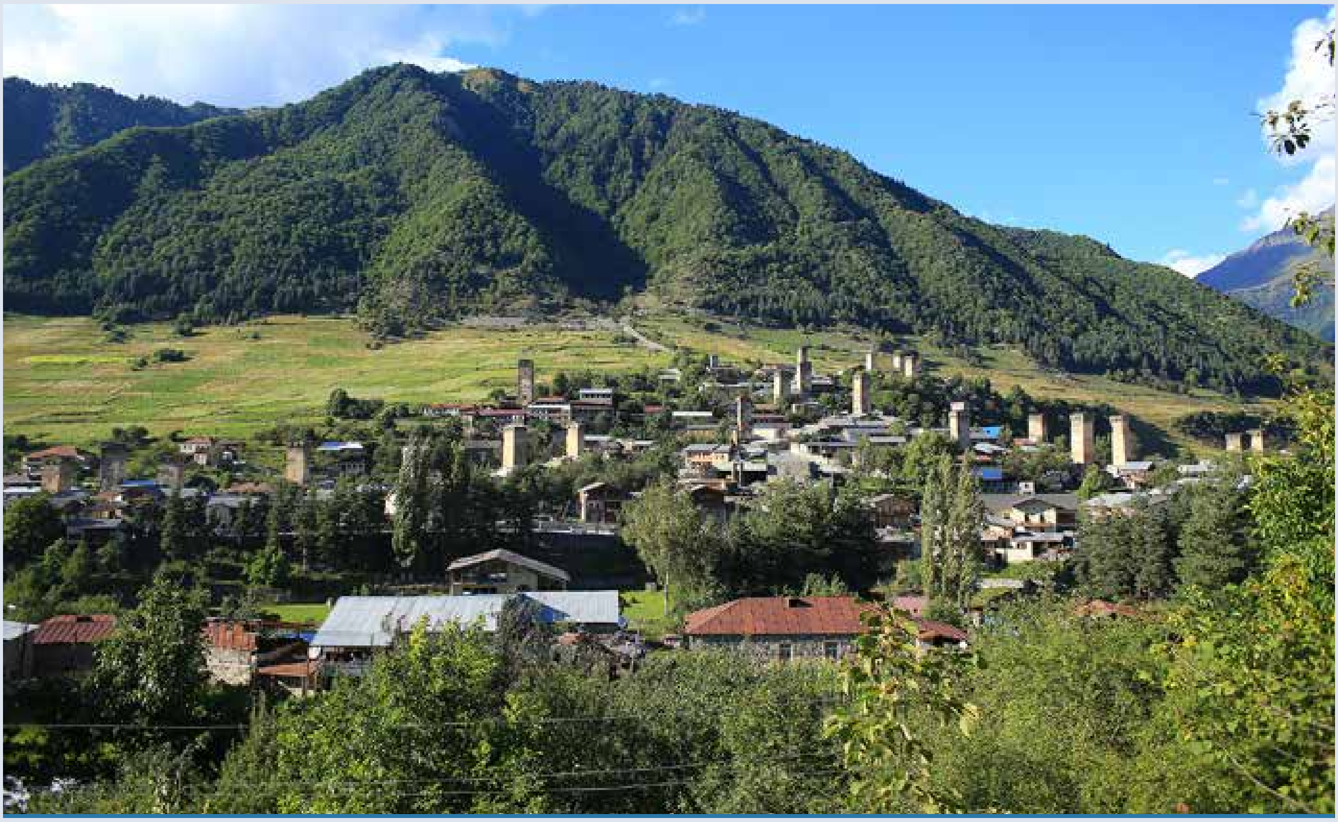
Micromaterial collection centres and reuse and recycle facilities could be set up to collect and treat appropriate volumes of waste at source before transporting and selling the collected material to a material recycling facility in a larger settlement. This could generate employment and income for the local community, while at the same time eliminating waste from accumulating in the environment.

Mini-transfer stations for solid waste in Georgia's mountain villages

Georgia's mountain regions have seen a rising problem of solid waste over recent years, mainly due to increasing population levels, growing tourism, and a rise in living standards. The New Waste Code, enacted in 2015, obliges municipalities across the country to prepare SWM plans by the end of 2017, which include the planning of equipment, collection schemes, and integration with other systems including spatial planning.

In the municipality of Mestia (the main town in the mountainous Upper Svaneti region), the government-owned Solid Waste Management Company is planning to set up a transfer station for municipal solid waste from the town and surrounding villages in the region. The plan is for the waste, once processed, to be transported to Zugdidi, 130 km away. The new regulations are expected to be challenging for the municipal authority, due to the burden posed on the municipal budget as a result of the high costs associated to waste management in mountain regions and a general lack of capacity. The situation in the more remote mountain villages might prove even more challenging, where there are practically no waste containers, and collection and removal of the waste is either ill-organized or absent at all. The conditions of the roads in these places is rather poor, making it impossible for the waste trucks to reach certain villages during the bad weather conditions.

One possible cost-effective option for villages, currently proposed by the Greens Movement of Georgia/Friends of the Earth Georgia, is to set up a series of mini transfer stations in these more remote villages, using existing means and input from the local communities. These stations would provide temporary storage for a period of between 3 to 6 months (depending on the size of the community and amount of waste generated), after which the municipal services would collect the waste and transport to the main transfer station in Mestia. Each station would include a waste segregation/separation area, allowing for the sorting of recyclable materials. Primary processing equipment, such as balers or compactors, could also be installed within, allowing the recyclable materials to be pressed – which has the benefit of reducing the volume and increasing available space, and making it more attractive for recycling companies to purchase. Such installations would be easy to operate after a short training.



Mestia, Georgia. *Photo © Wikimedia/Archil Sutiashvili*

Reducing open defecation in the Kailash Sacred Landscape, Hindu Kush Himalayas

An estimated 2.4 billion people lack access to improved sanitation, most of whom live in developing regions; the lowest coverage is in sub-Saharan Africa and Southern Asia (JMP, 2015). Eliminating open defecation is an important target under Sustainable Development Goal No 6. Community Led Total Sanitation (CLTS) is an approach that empowers local communities to eradicate open defecation and to build and use latrines. It was developed as a response to failed top-down development approaches – merely providing toilets or subsidies to build them did not guarantee their use or result in improved hygiene and sanitation (Kar and Pasteur, 2005). The CLTS approach focuses heavily on behavioural change, working to trigger a collective desire to change practices. The approach has spread to more than 70 countries across Asia, Africa and Latin America.

Open defecation In the Hindu Kush Himalayan region remains an important source of pollution for some of Asia's major rivers. The Kailash Sacred Landscape is an area shared between the Tibetan Autonomous Region of China, the Indian state of Uttarakhand and the far western region of Nepal. The area attracts pilgrims of the Buddhist, Hindu, Jain, Sikh and Tibetan Bön faiths, who come on pilgrimages around Mount Kailash. The area is also the headwaters of four of Asia's major rivers: the Indus, Sutlej, Karnali and Brahmaputra (Shrestha et al., 2015). However, unmanaged tourism in the area has resulted in inadequate waste disposal and sanitation, open defecation near sacred sites, unplanned and unattractive development, water pollution from ritual bathing in sacred lakes and adverse impacts on Ramsar wetlands (ICIMOD, 2015 and 2016).

The International Centre for Integrated Mountain Development (ICIMOD) has been working in the region to implement the CLTS approach within its overall landscape approach (Kailash Sacred Landscape Conservation and Development Initiative). Efforts in the Indian part of the Kailash have focused on eliminating open defecation in the forest community of Van Rajis. A one-year awareness-raising programme has resulted in the construction of 89 concrete toilets in all Van Raji villages. Nine Van Raji villages are on track to be declared Open Defecation Free by December 2016.

Encouraged by the success of CLTS, the district administration has initiated plans to replicate the process in neighbouring villages. In the Tibetan Autonomous Region CLTS has led to reduced incidences of open defecation in Huor and Darchen townships near Mt Kailash, through training of trainers and on the ground implementation support to local communities. On the Nepalese side of Kailash, the Humla district administration has adopted a CLTS approach to promote sanitation. The district is gearing up to an Open Defecation Free celebration in 2017. CLTS has helped to share best practices and transboundary knowledge to enhance sanitation and environmental protection in the Kailash landscape. Through a landscape approach, the initiative has been able to engage a broad perspective of stakeholders such as policymakers, practitioners, public agencies and local communities on this and other issues affecting this region.

Mount Kailash. *Photo © iStock/birdigol*

Himalayan toilet hut. *Photo © iStock/Paul Scotland*

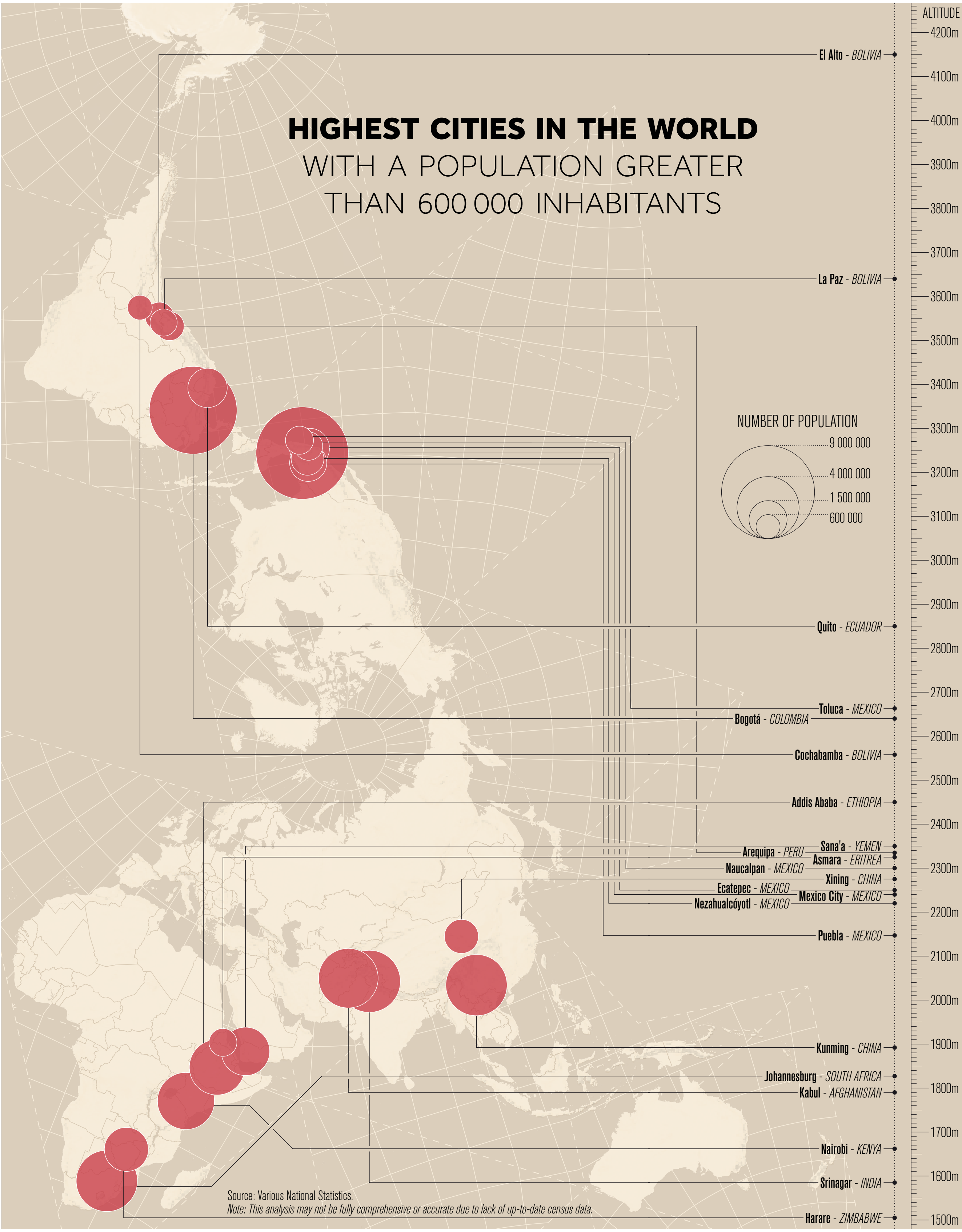
Mountain Cities and Urban Centres

In developing countries, the share of mountain populations living in cities is steadily increasing. Over one-quarter of mountain populations in the developing world now live in urban areas and cities (FAO, 2015). Large cities with one or several million inhabitants located at high elevations are predominantly a feature of the southern hemisphere and of low and lower middle-income countries. Latin America, Asia and Africa have numerous cities in this category. There are also many cities with fewer than 500,000 inhabitants located at high elevations in these regions. Globally, municipal solid waste is expected to double by 2025, putting huge pressure on urban public services; this will include an increase in variety as well as quantity (Hoornweg and Bhada-Tata, 2012).

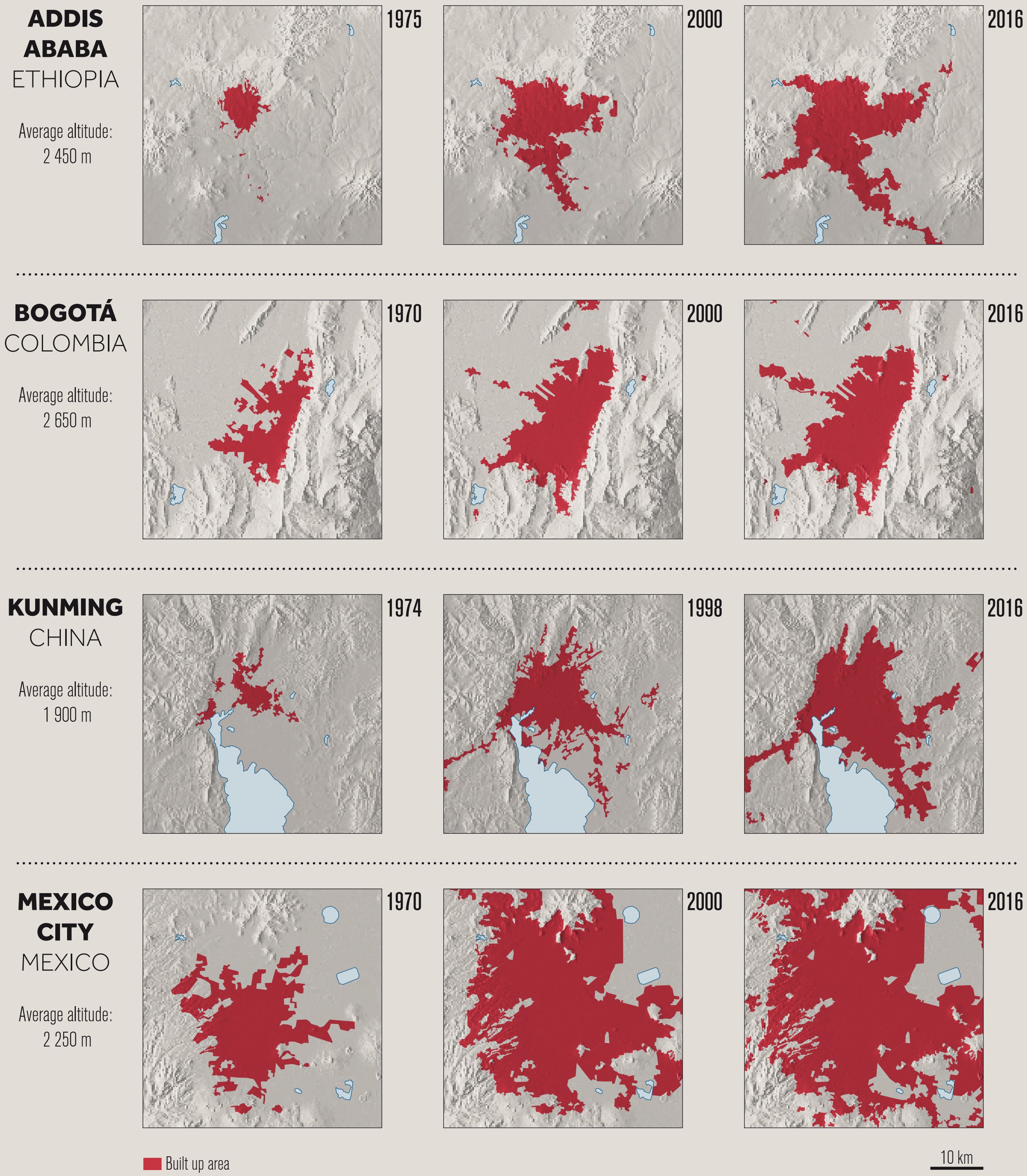
Mountain cities of Latin America, Asia and Africa

Most of the world's large mountainous cities[2] are found in the southern hemisphere in developing countries in the low to middle-income bracket; high mountain cities in developed countries do not have large populations. The Bolivian cities of El Alto and La Paz have the distinction of being the two highest cities in the world and are both part of a metropolitan region with a population approaching 2 million. Mexico City is by far the largest and is part of one of the largest metropolitan areas in the world; it includes the three cities of Ecatepec, Nezahualcoyotl and Naucalpan, all of which are over 2,000 metres above sea level (ASL). Other major medium to

El Alto, Bolivia. *Photo © iStock/fbxx*


HIGHEST CITIES IN THE WORLD
WITH A POPULATION GREATER THAN 600 000 INHABITANTS
NUMBER OF POPULATION
9 000 000
4 000 000
1 500 000
600 000
ALTITUDE
4200m
4100m
4000m
3900m
3800m
3700m
3600m
3500m
3400m
3300m
3200m
3100m
3000m
2900m
2800m
2700m
2600m
2500m
2400m
2300m
2200m
2100m
2000m
1900m
1800m
1700m
1600m
1500m
El Alto - BOLIVIA
La Paz - BOLIVIA
Quito - ECUADOR
Toluca - MEXICO
Bogotá - COLOMBIA
Cochabamba - BOLIVIA
Addis Ababa - ETHIOPIA
Sana'a - YEMEN
Arequipa - PERU
Asmara - ERITREA
Naucalpan - MEXICO
Xining - CHINA
Ecatepec - MEXICO
Mexico City - MEXICO
Nezahualcóyotl - MEXICO
Puebla - MEXICO
Kunming - CHINA
Johannesburg - SOUTH AFRICA
Kabul - AFGHANISTAN
Nairobi - KENYA
Srinagar - INDIA
Harare - ZIMBABWE
Source: Various National Statistics.
Note: This analysis may not be fully comprehensive or accurate due to lack of up-to-date census data.

URBAN GROWTH OF SELECTED MOUNTAIN CITIES



Sources: Google Earth (2016); Rymkiewicz & Kranert (2013) “Spatial integration of waste management data in urban areas: Addis Ababa,” *GGC*; Ferro & Roa (2018) “Bogotá: Ciudad densa y compacta,” *Camara de Comercio de Bogotá*; Burdett (2015) “A tale of four world cities,” *The Guardian*; Zhang & et al (2012) “Examining Land-Use/Land-Cover Change in the Lake Dianchi Watershed,” *IJERPH*; *Acuerdo por el que se expide el programa integral de transporte y vialidad 2007-2010* (2010) Secretaría de Transportes y Vialidad.

Kunming, China. *Photo © iStock/GoodLifeStudio*

large high altitude cities include Kathmandu (Nepal), Ulaanbaatar (Mongolia) and Kunming (China) in Asia; Harare (Zimbabwe), Addis Ababa (Ethiopia) in Africa; and Bogotá (Colombia), with more than 7 million inhabitants, in South America. Altitudes range from 1,350 metres ASL in Ulaanbaatar to more than 4,000 metres ASL in the case of El Alto, Bolivia. There are also numerous smaller cities (less than 500,000 inhabitants) between 1,500 and 5,000 metres ASL – particularly in Bolivia, Peru, Colombia, Ecuador, Mexico, India, China, Nepal, Kenya and Ethiopia.

Types and characteristics of solid waste in high mountain cities

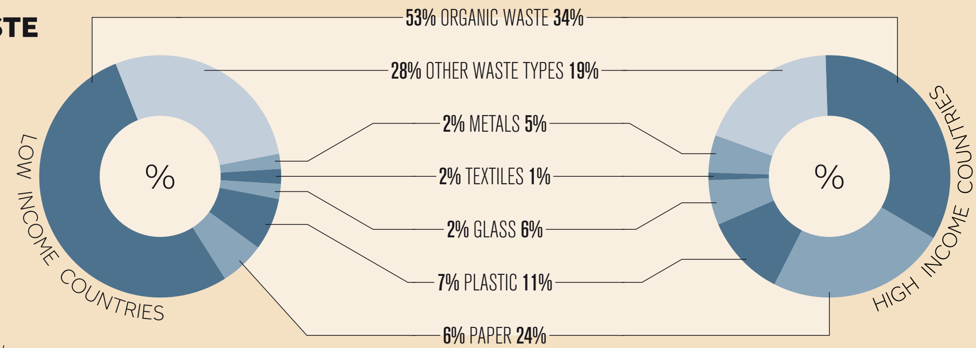
The characteristics of solid waste generated in large mountain cities relates more to levels of development than to altitude. Solid waste produced in mountainous cities in low and middle-income developing countries has a large component of organic waste (Modak, Wilson and Velis, 2015c); eating fresh food generates a large amount of food waste with limited amounts of packaging. However, there is a steady increase in the generation of non-organic recyclable waste, as income levels in these countries increases. This is expected to continue in the future: as the level of development increases, income per capita rises, which in turn means an increase in generation of waste per capita. The consequent increase in total solid waste will require proper management.

Another feature of the waste produced in these cities is the relatively small amount of hazardous household waste[3] (less than 1 per cent and up to 5 per cent if e-waste is included), although there are few reliable statistics.

The composition of waste is defined in terms of its physical characteristics – density, moisture content and calorific value – which in turn determines the technologies to be used for collection, transportation and treatment.

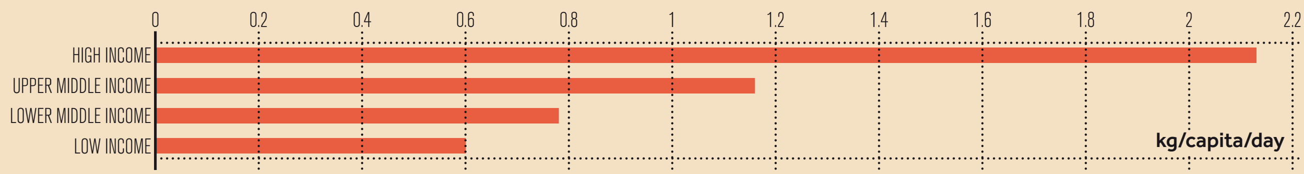
MUNICIPAL SOLID WASTE COMPOSITION

LOW INCOME COUNTRIES vs. HIGH INCOME COUNTRIES

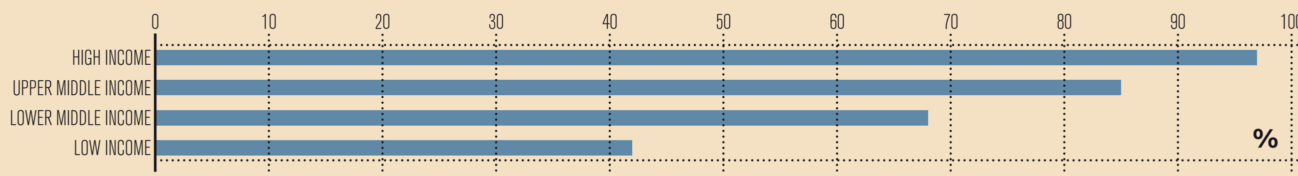


Source: UNEP & ISWA (2015) *Global Waste Management Outlook.*

AVERAGE MUNICIPAL SOLID WASTE GENERATION - ACCORDING TO COUNTRY INCOME LEVEL, 2010



AVERAGE MUNICIPAL SOLID WASTE COLLECTION EFFICENCY - ACCORDING TO COUNTRY INCOME LEVEL, 2010



Source: Hoornweg D. & Bhada-Tata P. (2012) *What a Waste: A Global Review of Solid Waste Management*, World Bank.

The UNEP methodology 'Sustainable Assessment of Technology'[4] (SAT) provides guidance on how to identify and select the best possible technology options, through an informed and participatory decision making process. The SAT Methodology can be adapted to country-specific needs and parameters. It integrates social, economic and environmental considerations.

Effects of altitude on solid waste and its management

The types of waste management at high altitudes are influenced by climatic and atmospheric conditions and soil characteristics, particularly the scheduling of street sweeping and collection services, the types of refuse collection vehicles used and the application of biological treatment of organic of waste.

The slower rate of decomposition and fermentation in weather conditions associated with high altitudes reduces the impact of waste on public health, the environment and aesthetics in mountain cities, particularly where there are deficiencies in urban cleaning services. Vector-borne diseases are more limited in number and variety, odour generation is not as immediate as in cities with warmer climates and the generation of leachate is relatively more controllable than in other cities at lower altitudes, because levels of rainfall are generally lower.

These conditions allow private or public operators to collect waste less frequently with a consequent reduction in collection costs, because inhabitants can store waste for longer in their homes. This also means that community containers can be used to store waste in densely populated residential areas – depending on the frequency of collection services (Scheinberg, Wilson and Rodic-Wiersma, 2010).

On the other hand, biological decomposition processes differ at higher altitudes. Lower temperatures can affect the decomposition of organic matter in composting processes (Cooperband, 2002). Despite this, biological treatment of organic solid waste (including composting or vermiculture) is still an option in some mountain cities (Coffey and Coad, 2010), providing care is taken to maintain temperatures suitable for the microorganisms responsible for generating compost or humus (which can then be used as a soil enricher).

Waste Collection trucks for the town of Uyuni, Bolivia. *Photo © SWM Department, Ministry of Environment and Water, Bolivia*

A waste collection truck in Bolivia. *Photo © Flickr/Jessica W*

The constraints on biological processes at altitude, therefore, need to be analysed in detail when planning for the application of biological treatment – not only for obtaining compost and/or humus from organic waste but also for treating leachates to reduce their potential for pollution prior to discharge into water bodies.

Governance of waste management in mountain cities

The types and characteristics of solid waste in large mountain cities relate more to levels of development rather than to altitude. This is also true for the way solid waste is managed. In general, the overarching structure of waste governance within urban settlements in mountainous regions is similar to that of waste governance in urban areas in other lowland parts of the country. The composition of stakeholders involved in the waste management process, as well as the goals and drivers, are essentially the same.

As with any urban area, the stakeholders in the governance of waste management in more mountainous regions consist of legislative bodies, government institutions, management authorities, waste generators, users of waste management services and waste handlers.

Generally, the political and administrative characteristics of a country defines the governance regimes. The role of national governments is to lay out the national policies pertaining to waste, and to design a strong, robust and transparent institutional framework for SWM. Such a framework should make clear which institutions and actors take on which roles at the different levels of waste governance. It includes both a broad legal framework of waste legislation, as well as more detailed regulations that allow for the effective implementation of the framework.

A common feature is that SWM is generally delegated to the government of the smallest territorial entity, usually the municipality. The role of government institutions at the local municipality level is primarily that of a client – the municipal government body takes on the role of a 'proxy-generator' of municipal solid waste. It is, therefore, the municipal government body that is responsible for collecting revenues to finance the SWM system, making executive decisions about who delivers SWM services such as waste handling and disposal, and which technologies are implemented. In making these decisions, it is crucial that they take into account efficiency, economy of scale and other relevant factors (Rodic, 2015c).

Waste handlers include government bodies responsible for the collection and disposal of waste, as well as private enterprises and stakeholders from the informal sector. Often government institutions issue tenders to private companies to undertake various aspects of the waste management process. Several studies (Rodic, 2015c; Scheinberg, Wilson and Rodic-Wiersma, 2010;

A waste collection truck in Bogota, Colombia. Photo © iStock/#NAME?

Thomas-Hope, 1998) have highlighted the importance of such public-private partnerships for increased efficiency and flexibility in waste governance. In Latin America, municipalities commonly exercise their responsibilities directly or through contracted private operators (large companies and/or microenterprises). Other arrangements can include public-private partnerships, cooperatives and microenterprises, which are often created to manage recycling.

Waste legislation in relation to mountains

National and sub-national legislation

National and sub-national legislation that specifically concerns waste management in mountain regions is largely non-existent. Mountain regions generally fall under the same national and sub-national waste legislation as other geographic regions and are not given any special consideration. Similarly, international legislation, such as conventions on waste management (for example, the Basel and Stockholm Conventions), apply equally to mountain regions, once adopted into national legislation.

Several countries have enacted national and sub-national laws for the equitable and sustainable development of mountains that may have some bearing on waste management practices in mountains. These laws aim to promote the socioeconomic development of mountain communities while simultaneously protecting mountain ecosystems. Examples of this approach can be found in Austria, Italy, France, Switzerland, Canada, Nepal, Georgia and Russia (North Ossetia/Alania).

International legislation

At the international level, there are only two mountain-specific conventions that address the sustainable development of mountain regions. These both have implications for waste management. The Alpine Convention is an international treaty bringing together eight European nations and the European Union for the sustainable development and protection of the European Alps. Article 2 includes an objective "to develop a system of waste collection, utilization and disposal which meets the special topographic, geological and climatic requirements of the Alpine region, paying particular attention to waste avoidance". The protocol for implementing soil conservation also touches (cursorily) upon the issue of waste management. A specific Implementing Protocol for waste management is yet to be formulated (Alpine Convention, n.d.).

The Framework Convention on the Protection and Sustainable Development of the Carpathians (Carpathian Convention) brings together seven states and is the only multi-level governance mechanism that applies to the entire mountainous region. Article 6 on 'Sustainable and Integrated Water/River Basin Management' refers to adequate sanitation and treatment of wastewater. The Convention does not directly refer to 'waste' but Article 10 on 'Industry and Energy' states that the parties to the convention "shall promote cleaner production technologies, in order to adequately prevent, respond to and remediate industrial accidents and their consequences, as well as to preserve human health and mountain ecosystems". It also states that parties "shall aim at reducing adverse impacts of mineral exploitation on the environment and ensuring adequate environmental surveillance on mining technologies and practices".

Other conventions have a specific bearing on mountain ecosystems, resources and populations. These include the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Convention to Combat Desertification (UNCCD) and the Convention on Biological Diversity (CBD). In light of the impact of human activities and waste on the environment, all of these conventions are concerned with waste management.

Declarations and 'soft-law' instruments also exist that concern mountain peoples and ecosystems. Chapter 13 of Agenda 21, 'Managing Fragile Ecosystems: Sustainable Mountain Development', recognizes the fragility of mountain ecosystems and outlines the environmentally-sound management of municipal solid waste. This includes maximizing the 3Rs (Reuse-Reduce-Recycle) for safe and sound waste management.

Two of the 17 Sustainable Development Goals emphasize the importance of pursuing sustainable mountain development. Mountain-related targets are listed under goal 6.6, which aims to "… protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers..." and goal 15.4, which aims to "… ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development" (United Nations Sustainable Development Knowledge Platform, 2015).

The informal sector[5] plays a significant role in waste handling and sorting processes in developing nations. The informal recycling sector may be saving cities as much as 15 to 20 per cent of their waste management budget. At the same time, if revenues for some materials decrease, collection is no longer secured. Workers in the informal sector often work in extremely unhygienic conditions, with a high risk of accidents and disease (Binion and Gutberlet, 2012; Jerie, 2016). This can extend social inequalities if these workers are not included in a formalisation programme.

The typical management of solid waste includes service delivery – sweeping, collection, transportation and disposal of solid waste – and treatment and resource recovery, mainly of organic waste (through composting) and of recyclable waste (through recovery, sorting and sale). The level of recycling remains basic because it has not been possible to implement integral systems to produce recycled products on a large scale. Generally, the proportion of organic matter exceeds recyclables by a ratio of 2:1. However, municipalities are working towards a greater emphasis on recycling waste that can be used in industry. SWM options are prioritized in an order known as the Waste Management Hierarchy.[6] In general, landfill sites are used for disposal, although in some mountain cities there are still many open dumping sites.

Challenges and risks

SWM in large mountain cities, as in other cities in developing countries, is often inadequate or poor. While most countries have legislation on SWM, it is generally only partially implemented.

Insufficient and poor SWM manifests itself through low levels of collection coverage, mixed waste collection without separation at source, informal recycling of waste on the streets and disposal of solid waste in open dumping sites (as opposed to sanitary landfills). In most cities in developing countries, including large mountainous cities, collection coverage is relatively low, ranging from 30 to 60 per cent in low-income countries and from 50 to 80 per cent in middle-income countries (Scheinberg, Wilson and Rodic-Wiersma, 2010).

The accumulation of solid waste in streets or in open dumpsites has significant negative impacts on human health and the environment. When waste in open dumps is not covered, it can produce unpleasant odours, biogas and leachate contaminants that can adversely affect air quality, rivers, underground water sources and soils. Water bodies

A waste dump on the edge of the Bagmati River, Kathmandu. Photo © Flickr/az zut are polluted by non-collected waste or leachates produced at dumpsites. This same water is used for drinking, cooking, cleaning or for irrigating crops. The disposal of mixed municipal waste containing hazardous medical and household waste, can cause further pollution.

Other public health issues from dumpsites include the proliferation of disease-vectors such as rats, mice, flies and other pests that feed on waste. Often, domestic animals feed on waste in open dumping sites, a common practice in many cities in developing countries. These animals also act as vectors, especially of parasitic diseases. The weather and atmospheric conditions at higher altitudes, however, hinders the proliferation of mosquitoes, insects or other species of pests common in lowland cities with more tropical climates.

Nonetheless, the effects of open dumping can be particularly harmful to sensitive mountain ecosystems. Furthermore, the effects of dumping waste in river gorges has the potential to impact very large populations as the river waters are used by millions of people living on the floodplains. Uncontrolled burning is often used as an easy way of getting rid of waste or reducing the volume of waste. However, the smoke produced by burning waste creates risks because of the generation of particulate matter and other hazardous gases emitted into the atmosphere.

Air pollution is affected by changes in altitude; incomplete fuel combustion occurs when there are lower levels of oxygen, leading to higher amounts of suspended particles, otherwise known as soot (EPA, 1978). The effects of altitude are not always taken into account in setting standards for air quality. For example, current air quality standards for particulate matter (PM) in some high-altitude cities (El Alto, Medellin and Mexico City) are thought to underestimate the important effects of altitude (reductions in temperature and pressure), which might explain why there is a rising prevalence of asthma and allergies in high-altitude urban areas in Latin America (Bravo Alvarez et al., 2013).

The people most likely to be at risk are those living in peri-urban, low-income areas who do not have an adequate collection service, people living in areas adjacent to open dumping sites, especially children and the elderly, and personnel working for urban cleansing services (Scheinberg, Wilson and Rodic-Wiersma, 2010).

Air pollution over Mexico city. *Photo © iStock/jcarillet*

K'ara K'ara dumpsite – engaging the private and informal sector in waste management

The K'ara K'ara dumpsite is located in Cochabamba, Bolivia and is about 25 ha in size. The total amount of waste in this landfill is estimated to be between 2.8 and 4 million tonnes; the Ministry of Environment and Water (2010) considers it to be a controlled disposal site. K'ara K'ara's operations have been subject to health-related discussions because of its proximity (about 200m) to a nearby settlement. About 5,000 people have settled around the site since operations started in 1987 and Cochabamba city's population of approximately 670,000 live within 10 km of the dumpsite (National Statistics Institute, Bolivia, n.d.). Cochabamba is one of the biggest cities in Bolivia and generates about 500 tons of domestic waste a day, of which 61 per cent is organic and 18 per cent is recyclable (Rodic, 2015a).

Problems and solutions

The K'ara K'ara dumpsite has had a sizeable impact on the local population and surrounding environment. The site has caused significant environmental damage in the area, particularly to water quality. The population has been unable to use the local groundwater following tests in 1999 which showed that it was highly polluted (Bustamante and Médieu, 2012).

The environmental damage is a result of a poor operations over many years by the municipal enterprise. However, a few years ago, a national private company was contracted to take over operations and to develop plans to close the site. These measures have improved the situation. Until recently, Bolivia did not separate the different types of waste at source. However, in 2015 a Waste Management Law was approved – as part of the National Programme of Solid Waste Management – which enforces source separation, recycling and resource recovery activities, and separates collection for different types of waste, including special and hazardous waste. Currently, 91 per cent of Bolivia's landfilling is open air dumping without any form of control, fencing, leachate drainage or gas control. The remaining 9 per cent consists of controlled dumping and sanitary landfilling (BreAd B.V. and MetaSus, 2015).

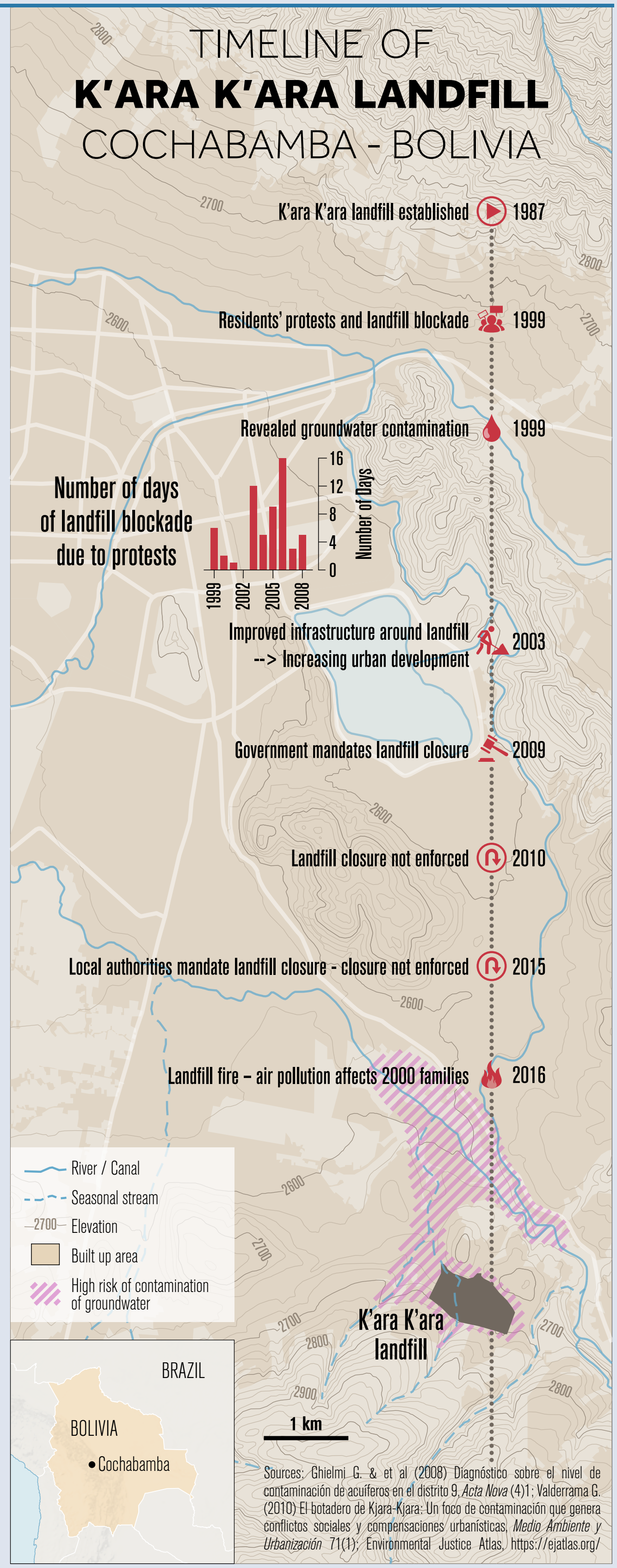
In recent years, the national, departmental and municipal governments have made efforts to undertake formal recycling, but the collection of recyclable waste is mainly carried out by the informal sector, which consists of waste pickers who often have no other means of securing an income. Approximately 175 tonnes are collected by waste pickers every day across the country (De la Parra Leibson, 2012), providing a significant contribution to the country's economy and waste management. This has been recognized in the recent Law of Waste.

Cochabamba City as viewed from the controlled dumpsite K'ara K'ara. *Photo © SWM Department, Ministry of Environment and Water, Bolivia*

Reducing volumes of waste and promoting source separation Swisscontact has made a significant contribution to addressing the waste problem in Cochabamba. Their activities have included the implementation of separate collection schemes in Cochabamba neighbourhoods, operated by informal recyclers and supervised by the neighbourhood council. The project demonstrated the economic potential of solid waste by establishing new structures for collection, treatment and recycling. A 50 per cent reduction of mixed waste was realized in one district and separation at source was included in SWM plans. (Rodic, 2015a)

Collection routes were also established for informal recyclers, with households separating recyclables and passing them on. This programme allowed waste pickers to generate an income of about 1,200 Bolivian Boliviano per month (175 USD) and contributed to higher recycling rates as well as an acknowledgement of the role of informal waste pickers. This programme is now integrated into the municipality's waste management system. Between 2009 and 2012, a total of 443 jobs were created, 29,000 tons of solid waste were collected and treated, and information on the separation of waste at source was provided to 475,000 households (Rodic, 2015a).

Bolivia is making a concerted effort to move away from dumping and landfilling, towards initiatives that focus on small-scale open air composting of organic waste. Municipal waste trucks have started to collect organics, recyclables and residual waste separately, and private recycling companies are emerging which use materials from industry and storage centres (they receive materials from waste pickers). The future of the Bolivian waste market appears to be positive – with new investments and initiatives, and good intentions are all around (BreAd B.V. and MetaSus, 2015). In 2012, Bolivia invested USD 20 million in waste management (Environment News Service, 2012) and the growth in demand for waste is estimated to be 1 per cent per year (BreAd B.V. and MetaSus, 2015). Although these numbers are promising, efforts are still small-scale and scattered, and new initiatives are needed. Opportunities exist for private companies (which already play an important role in waste collection and operation services) to engage in waste management (for example, biogas production) and cooperation is needed to make waste composting and sanitary landfills more viable. These developments will create a more effective waste management system, which may increase the willingness of the population to pay for waste services.



Innovations and opportunities in solid waste management in mountain cities

Despite the various challenges of implementing SWM in large mountain cities (which as alluded to earlier, relate more to levels of development than altitude/terrain), there are valuable lessons and examples of good practice that can be drawn on from a number of mountain cities:

Policies and legislation

Some countries have made significant progress on waste legislation over recent years. Peru (Del Pilar Tello Espinoza et al., 2010) and Bolivia[7] recently approved laws on waste. Ecuador and Colombia also have well-developed national legal frameworks that drive the development of local regulations, which apply to large mountainous cities. Mexico has federal and state legislation, as well as local regulations. In Nairobi, the City Council has established policies for the operation of services, private participation in recycling and composting, and the formal registration of collectors.

Creation of metropolitan organizations and economies of scale

Initiatives to create metropolitan organizations that bring together local governments and municipalities have, in some cases, improved SWM by generating economies of scale and optimizing the use of land for landfills, treatment plants and recycling. Examples include the metropolitan area comprising La Paz, El Alto and four other Bolivian municipalities. Also in Bolivia, a metropolitan region, Kanata, was created to provide solutions to common problems through joint integrated projects, including the implementation of a metropolitan SWM project. Kanata comprises the city of Cochabamba and six smaller municipalities.

Composting

Composting is one way for municipalities to recycle and reduce the amount of waste which ends up in dumpsites and landfills, helping to extend the lifetime of landfills and reducing the amount of leachates, greenhouse gases and other pollutants. Composting of organic waste is increasingly common, particularly where there is a market for compost in urban horticulture and local farming (Coffey and Coad, 2010). South Africa has a

Leachate treatment facilities for a landfill in La Paz, Bolivia. *Photo © SWM Department, Ministry of Environment and Water, Bolivia* wealth of experience due to the demand from its agricultural sector (UNEP and ISWA, 2015). In 2012, Mexico City opened its first large-scale composting plant, with the intention of using the compost to fertilize parks and green spaces, with plans to eventually sell it to agricultural producers (Villagran, 2012). Bolivian cities also have experience in developing small-scale manual or semi-mechanized composting plants. Such initiatives can help generate employment, enhance the social inclusion of waste pickers and encourage the further use of composting.

Recycling and social inclusion

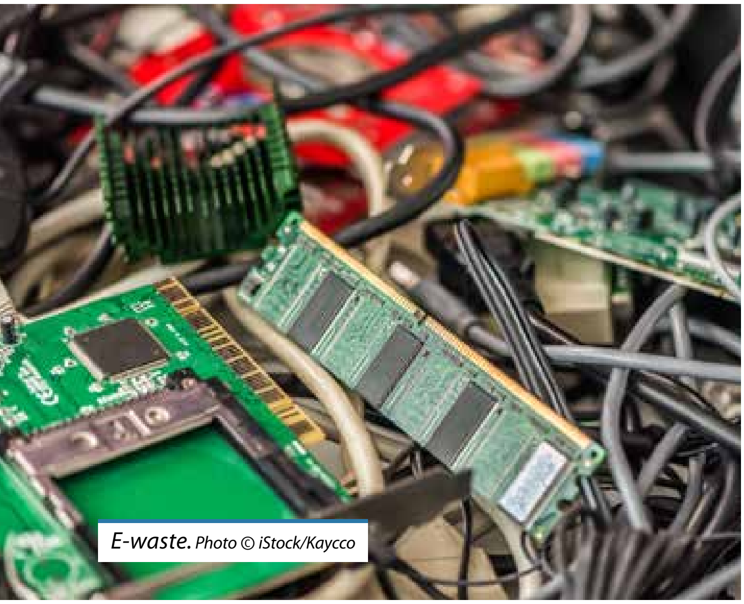
The recycling of paper, plastics, glass and metals, has also been on the rise in several mountainous developing countries and cities, with initiatives also promoting the social inclusion of informal recyclers working on the streets and in open dumps. Since 2011, the city of Bogotá (Colombia) has promoted separation at source, acknowledged the role of waste pickers, financed the purchase of motorized vehicles and established a storage network for recyclable materials. Currently over 8,000 waste pickers are part of the 'Bogotá Zero Waste' Programme. There are plans to replicate this model throughout the country (Rodic, 2015b). Cities in Ecuador and Colombia are also making efforts to promote separation at source, develop separate collections and improve workers' conditions.

Nairobi has created the largest market for recyclable waste in Africa – involving more than 100 private companies, microenterprizes and community associations. However, the social inclusion of informal recyclers remains an issue (Scheinberg, Wilson and Rodic-Wiersma, 2010). Harare (Zimbabwe) has also developed an important market for recyclable materials, which they receive from neighbouring countries such as Zambia (Scheinberg, Wilson and Rodic-Wiersma, 2010). Mexico and South Africa use significant amounts of recycled paper and cardboard (Modak, Wilson and Velis, 2015f).

Management of E-waste

The increasing use of electronic devices such as computers, monitors, printers, mobile phones, refrigerators, microwave ovens, batteries and other devices, and the frequency with which people

Recycling truck with cardboard, Mexico City. *Photo © iStock/JHMimagine*



E-waste. *Photo © iStock/Kaycco*

change these devices, has led to a growing problem of electronic waste (e-waste). Launched in 2010 in Nairobi, and the first of its kind in East Africa, the Waste Electrical and Electronic Equipment Centre is a not-for profit organization operated by local entrepreneurs that collects, dismantles and processes e-waste for the capital and several other major Kenyan cities. Similarly, the East African Compliant Recycling Company is working with the private sector in Nairobi and other Kenyan cities to collect and treat cathode ray tube monitors. These initiatives have helped in the development of the first legislation on e-waste (under the leadership of Kenya's National Environmental Management Agency). Similarly, in Latin America, e-waste is becoming a priority for national and local governments and has generated significant private sector involvement (although still on a small scale). In some of Colombia's major cities, separation of e-waste at source is already taking place.

Construction of landfills

Both Colombia and Mexico have managed to reduce the use of open dumps as a method of solid waste disposal (Del Pilar Tello Espinoza et al., 2010). In other Latin America countries, the proportion of the population covered by sanitary landfills is relatively low,[8] mainly because of the low priority given by local authorities to the issue, the costs involved and investment needed for the operation and maintenance of landfills, and institutional weakness – particularly the failure to enforce existing laws and regulations. In Kunming (China) there are two landfills in operation, one of which is financed through a carbon credit project (Scheinberg, Wilson and Rodic-Wiersma, 2010). In other low-income countries such as Ethiopia and the Republic of Yemen, the prospects are less optimistic, largely because of poverty and internal conflicts.

Mountain landfill. Photo © iStock/huseyintuncer

Developing an Integrated Solid Waste Management Plan for Maseru City, Lesotho

Lesotho is a mountainous, landlocked country entirely surrounded by South Africa. It's capital, Maseru, is the largest city in the country. Before 2006 there was no sanitary landfill for the city and recycling rates were low (less than 10%). Waste was dumped into an old quarry where the waste was subsequently burnt, causing air pollution and health risks. Toxic substances also leached into the city's water reservoir.

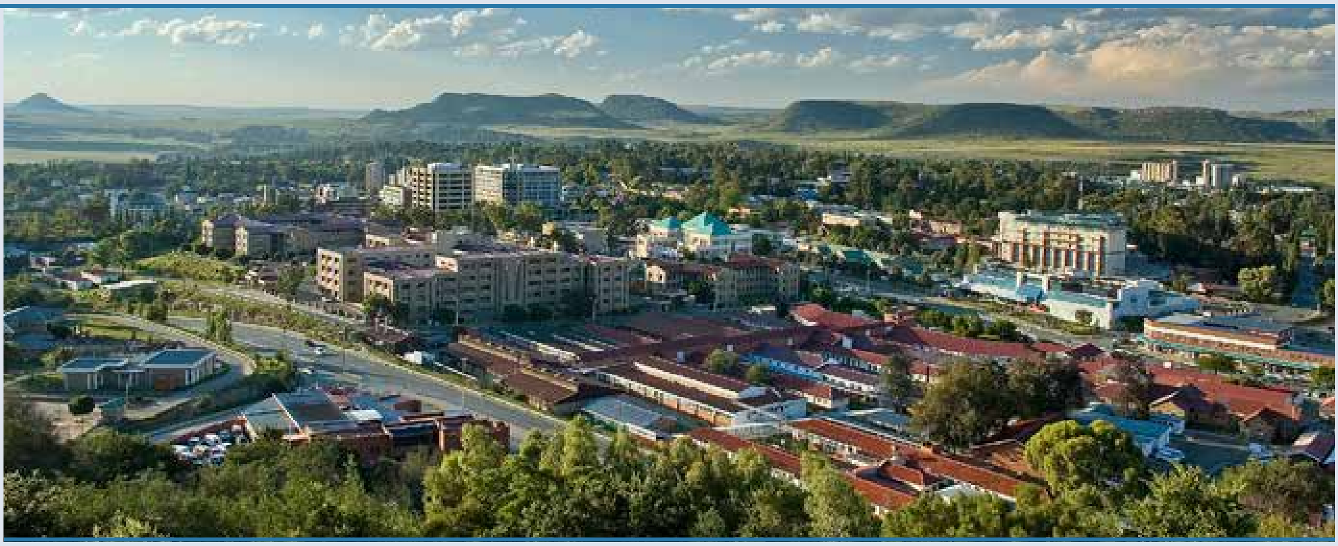
In order to introduce a more strategic and integrated approach to managing growing amounts of waste, the UNEP International Environmental Technology Centre (IETC) provided technical assistance to the city to develop an Integrated Solid Waste Management Plan (ISWMP). Following a baseline survey conducted in 2006, the ISWMP was completed in early 2008, led by the Ministry of Local Government with advisory and technical assistance from UNEP IETC in partnership with the University of Cape Town.

The Plan consists of 5 main pillars, which are further sub-divided into 20 different actions. These five pillars of the plan, and actions include:

- Capacity to prevent wasteful resource use at source. Actions include promoting sustainable consumption, cleaner production, source separation, and at-source value addition.
- Strong, diversified and appropriate collection systems: Actions include developing different collection systems for different areas, including decentralized waste depots, the integration of informal waste pickers, route planning,
- A healthy recycling industry: Actions include providing business development support and support to industry associations to promote recycling, and revising the regulatory framework to support local recycling markets
- Environmental safe disposal site: Actions Include the development of an Environmental Impact Assessment for the proposed sanitary landfill site, integration of the site with other on-going activities, and providing capacity to convert paper waste into paper bricks for fuel.
- Foundation (Education and Capacity Building): Actions include awareness raising in schools, creating waste minimisation clubs, establishing a waste information system, and creating awareness through mass media.

Following this effort, UNDP initiated the 'Innovative Partnerships for Solid Waste Management (IPSWM)' Project in Lesotho between 2009 and 2012. The objective of the IPSWM Project was to support the development of financially sustainable and innovative public private partnerships (PPPs) for basic delivery of sustainable solid waste management services. This included waste collection, street sweeping, waste picking and recycling within the urban and peri-urban areas of Maseru.

Pamphlet promoting recycling and behavioural change, designed for primary school children and parents as a call for action. Created by the University of Cape Town and the UNEP International Environmental Technology Centre (IETC) as part of the education and awareness raising activities, within the project 'Integrated Solid Waste Management Plan for Maseru City'.



Maseru, Lesotho. *Photo © iStock/pg-images*

Some barriers still remain for the effective implementation of the Integrated Solid Waste Management Plan. These include having the necessary institutional capacity to contract, manage and monitor solid waste management service delivery arrangements, basic technical and management capacity of service providers, policy enforcement, and public awareness and action to reduce, reuse and recycle waste.

According to the 2006 baseline assessment for the development of the Integrated Solid Waste Management System, the industrial sector accounts for one third of Maseru's municipal solid waste. Maseru has a fairly large knitted textile industry which also produces hazardous wastes (University of Cape Town and UNEP, 2006). *Photo © John Hogg, World Bank*

Financing Solid Waste Management in Communities and Cities

Generating a culture of paying for services to cover all or part of operational costs, is an important step in improving SWM. Several mountain cities have been successful in this regard, often as a result of new, higher-quality services. Nairobi is a good example; people are more willing to pay when their neighbourhoods are clean and free of waste (Scheinberg, Wilson and Rodic-Wiersma, 2010). The delivery of services through the private sector (including large companies and microenterprises) as well as through cooperatives and community associations has also been shown to be effective in developing countries. In more remote mountain regions, community-based financing based on voluntary mechanisms, tourism revenue or the sale of recyclable materials (where possible) may be more appropriate.

User fees for solid waste management services and its challenges

Public municipalities and private firms have many costs to cover for managing solid waste, including transportation and fleet maintenance, fuel, paying waste collectors, and maintaining treatment and sorting facilities.

Cost recovery tariffs and fees are commonly used to cover these costs, especially in the case of commercially-driven operators or to finance quality improvements. However, it is often difficult to collect or increase tariffs/fees to cover the real costs or to finance improvements due to a perceived lack of public demand for services and/or and a lack of public willingness to pay. Fixed fees do not take into account the variability in solid waste produced among households. Different social groups often differ in their willingness to pay for municipal waste services (UNEP, 2005). Income-based tariffs can incorporate the ability to pay into user charges, while surveys on acceptable levels of payment can include the public in setting rates (GIZ, 2015). However, these types of charges offer little incentive for waste reduction.

Some tariffs also aim to reduce the amount of solid waste produced. 'Pay-as-you-throw' schemes are one example, charging fees to households and firms based on volumes and weights of discarded waste. This can lower the costs for poor families in peripheral regions who produce little waste and cannot pay service fees. However, it can also encourage illegal dumping and requires investment in both monitoring systems and enforcement strategies. Payments may also be more irregular than with weekly or monthly charges, creating budgeting challenges for service providers.

Both private and public models for SWM are used across the world and there is no evidence to suggest that either is more efficient in recovering costs (UNEP and ISWA, 2015). Recent approaches often entail greater collaboration between state and non-state actors – be it private investors, informal workers, central and local state organizations or volunteers. However, all waste service providers need to recognize that vulnerable and low-income households may not be able to afford increases in fees that come with improvements in SWM or profit-seeking in the waste sector. In addition, poor households in remote mountain regions that are not served by municipal services do benefit. This may also be the case for slums and rural communities. Thus, raising awareness of the importance of waste management and the participation of all stakeholders is a necessary precondition for implementing user fees. In some cases, it may be necessary to charge higher fees to higher income households, to support to those who cannot afford to pay. Systems for collecting variable taxes and tariffs must be transparent and acknowledge public needs and traditions, to work effectively (UNEP and ISWA, 2015).

Earning a living from waste: informal waste pickers

The reality in many developing and transitional countries is that municipal services are often not able to cover all households. A common approach for activists and residents is to self-organize to tackle local challenges.

Informal waste pickers often fill this gap and contribute significantly to waste management by collecting, sorting, trading and sometimes processing waste materials. Globally, of the estimated 19-24 million people currently working in waste management and recycling, only 4 million are in formal employment. The rest are informal workers, mainly waste pickers in developing countries, many of them women (ILO, 2013). In some countries, the informal waste sector employs as much as 1 per cent of the urban

Informal recycling in Thailand. *Photo © Shutterstock/toowaret*

population and recovers up to 20 per cent of municipal waste (Gunsilius, 2010). The drivers may not only be waste and pollution, but also unemployment and poverty. The informal sector is able to achieve high recovery rates (up to 80 per cent) because sourcing recyclable materials is critical for waste pickers' livelihoods. However, informal waste pickers tend not to adhere to acceptable environment standards and informal sorting and recycling practices often disposes of waste directly into the environment (Gunsilius, 2010). Waste pickers often work in extremely dangerous conditions and are exposed to contaminated and toxic materials. Child labour is common, and life expectancy can be very low. Waste pickers are often socially excluded and economically marginalized, and among the most vulnerable groups in society. Their incomes are susceptible to fluctuations in the market value of recyclable material. Where waste pickers organize themselves into cooperatives, fixed wages can lead to market distortions and a lack of incentive for collection and sorting.

Informal waste pickers suffer from a lack of recognition and can be marginalized when municipalities seek to modernize waste management – the focus often shifts to efficient collection and disposal, rather the than recovery and recycling of waste, denying access to waste resources. Many waste pickers are now forming organizations and cooperatives, to gain recognition, negotiate with municipalities and lobby for inclusive waste management models (WIEGO, 2013; Ezeah et al., 2013). There are cases in Asian and Latin American countries where waste pickers' organizations and cooperatives have become regular partners with municipal governments and private sector enterprises (Gunsilius, 2010).

The extent of formal and informal approaches to waste management (by waste pickers) in more remote mountain regions depends on localized economic incentives. In many cases, insufficient quantities of recyclable waste are generated to make recycling a profitable and economically viable enterprise, and might discourage informal work. Other factors such as high transportation costs associated with more remote mountain areas could also affect prices and make collecting sellable materials less economically viable. Furthermore, harsh climates may increase the costs of sorting waste.

Household waste pickup, Kathmandu. *Photo © Wikimedia/Sigismund von Dobschütz*

Lessons from community initiatives

Community-based financing based on voluntary mechanisms, tourism revenue or the sale of recyclable materials (where possible) are often more appropriate in remote mountain regions. It is difficult to attract companies and state municipalities to invest in these areas due to weak property rights, high service costs and poor banking services. However, because community groups often lack access to financing options, it is important to ensure ways of increasing the incentive and capacity to self-manage and decrease waste.

Mechanisms such as cooperative funds – reserves of money, managed by cooperative members – could be used to address these challenges. Cooperative funds could be used for building waste infrastructure, maintaining vehicles and subsidizing incomes when prices of sellable waste are low (Achtell, 2013). However, these often require access to public banks, which may not exist in remote areas and the logistical arrangements for accessing funds may be too complex.

Financial incentives such as grants for small-scale recycling or composting projects could encourage other small-scale systems on a wider scale. However, any financial allocations and their payment criteria must be well defined and widely publicized among community groups through information campaigns (Ali and Snel, 1999).

There are potential pitfalls to community approaches including organizations running over budget and being unable to pay workers their full wage. There are also aspects of gender inequality to be considered – jobs primarily done by women, such as sorting and cleaning recyclables, are often undervalued and not recognized as part of the waste system (GIZ, 2008). Consultations, calculating full costs and transparent budgeting is necessary to increase efficiency and equity. In remote mountain communities, it is often too costly for municipalities alone to provide a working service for inhabitants because of limited resources. In tourist destinations, engaging the tourism sector (in providing revenue and volunteers) can help small-scale sustainable waste projects.

Climate mitigation financing for solid waste management

Because waste contributes to global emissions of greenhouse gases and Short Lived Climate Pollutants (SLCPs), including methane, efforts that seek to reduce emissions through improved waste management techniques are eligible for mitigation financing. For the past 10 years, the Clean Development Mechanism (CDM) has been one of the main financial mechanisms for mitigating climate change, allowing developing countries to earn carbon credits (certified emission reductions – CERs) for projects which reduce greenhouse gas emissions. These are then sold to emitters in rich countries seeking flexibility in their attempts to reach the emissions targets set out by the Kyoto Protocol (1997). The aim is to finance sustainable development in poor countries through money transfers from rich polluters.

Currently around 12 per cent of CDM registered projects relate to SWM (UNFCCC, 2016). CDM projects are required to measure baseline emissions and continuously monitor reductions, as well as find potential buyers for CER credits and secure financial resources until CERs are sold. This makes it difficult for small-scale projects in mountain regions to qualify for funding. As it stands there are very few SWM projects in remote mountain areas funded by the CDM. Those that do exist tend to be incinerator projects; accounting for reductions in methane emissions (which would otherwise be generated by landfills) allows them to qualify for CDM financing. For waste pickers and community recyclers, however, calculating and proving emissions reductions is a key challenge.

Nationally Appropriate Mitigation Actions (NAMA) are reflective of the need for greater and more diverse financing options to meet the aims of the Paris (2015) agreement. NAMAs include "any action that reduces emissions in developing countries and is prepared under the umbrella of a national governmental initiative" (UNFCCC, 2014). The benefit of NAMAs is that, rather than relying on demand for CERs from rich emitters, actions are determined and undertaken by developing countries to meet their own emissions targets. While they often require financial and technical support from the international community, the underlying aims and processes differ from those of the CDM. Similarly, many countries, through their Intended Nationally Determined contributions (INDCs), have identified sound waste management as one of the key initiatives to implement in order to reduce GHG emissions.

Shifting responsibilities from municipalities to producers through Extended Producer Responsibility

Extended Producer Responsibility (EPR) is a policy tool whereby producers assume responsibility for managing the waste generated by their products. EPR programmes generally have two objectives: to increase collection and recycling rates of targeted products and materials, and to shift financial responsibility for managing product waste from municipalities to producers (OECD, 2014). In doing so, EPR can help to improve recycling and reduce landfilling. It is also intended to encourage producers to reduce the environmental footprint of products through changes to their design, making their products more suitable for reuse and recycling and reducing the number of hazardous substances within them.

EPR first appeared in Europe in the early 1990s and since then the approach has spread to other countries. All European Union member states have implemented EPR schemes[9] for four waste streams – packaging, batteries, end-of-life vehicles and electrical and electronic equipment. Several countries also implement EPR for tyres, graphic paper, oil and medical waste. Beyond Europe, most OECD member countries and many emerging economies have EPR programmes in place; EPR programmes are also in the scoping phase in several developing countries in Asia (e.g. China), Africa (e.g. Kenya) and South America (e.g. Colombia) (OECD, 2014).

A significant number of EPR programmes have been implemented over the last 15 years, allowing for an analysis of their effectiveness across different measures. EPR has been effective in a number of ways, including higher collection and recycling rates; reduced public spending on waste management; a reduction in overall waste management costs (OECD, 2006 and 2014); and the introduction of new product designs with smaller environmental footprints (Europen, 2014). EPR coverage, however, is not comprehensive and currently does not cover all non-biowaste streams. For example, an analysis of 15 European cities found that on average, less than 18 per cent of total waste is collected through EPR schemes (Sanz et al., 2015). In addition EPR programmes do not always cover the full costs of collection and recovery of specific waste streams. The new Circular Economy Package for Europe, planned for adoption in 2017 or 2018, states that EPR programmes should cover the full costs of collection and recovery for specific waste streams. Should such legislation enter into force, it will lead to a significant increase in waste covered by EPR and a rise in collection and recovery rates across the EU.

Financing solid waste management in Tajikistan and Kyrgyzstan – the two most mountainous countries of Central Asia

Tajikistan and Kyrgyzstan, which both have an average elevation of about 3000 metres, are truly mountainous countries with limited space and conditions for safe waste storage, be it municipal waste or hazardous industrial waste. The legacy wastes of former uranium and heavy metals production and unstable tailings, which are prone to wind and water erosion and landslide risks, are painful reminders of the long-term implications of improper waste management.

The current SWM systems in both countries are underfunded, with low levels of official and informal recycling rates. Both the waste tariffs and awareness about the need to reduce and recycle, are also low. In Tajikistan the state enterprise on housing and communal services “Manziliyu Kommunali” is responsible for waste management across the country, while in Kyrgyzstan several municipal waste companies serve the main cities. Waste collection in rural areas is almost non-existent, but waste generation in rural areas is lower and recycling and composting is more prevalent.

In both countries international financial institutions, such as the European Bank for Reconstruction and Development, are helping to improve waste collection and delivery services in the major urban centres and expand waste collection coverage to the nearby rural and semi-urban areas. Local authorities and residents are optimistic about the upcoming waste system improvements. UN Environment (UNEP) has assisted Tajikistan is developing the National Waste Management Strategy till 2030 (under review) and has supported Kyrgyzstan in research and action on mercury waste.

More detailed information about SWM in the main cities and countries of Central Asia will be available in the upcoming UNEP Regional Waste Outlook on Central Asia.

Dushanbe city landfill, Tajikistan. *Photo © Zoi Environment Network*

Widespread illegal practice of municipal waste open burning in Kyrgyzstan 10 years ago. *Photo © Union of the photo-journalists of Kyrgyzstan Network*

In Kyrgyzstan today many waste collection points are video-monitored and there is less open waste burning. *Photo © Zoi Environment Network*

Adventure Tourism and Recreation: Mountaineering and Trekking

Mountaineering and mountain trekking are forms of adventure tourism and recreation that are increasing in popularity globally (World Tourism Organization, 2014). These activities carry with them waste implications, both at lower elevations and in high-altitude, uninhabited and often extreme environments. Due to their remote location, mountaineering and trekking areas often do not have any sanitation facilities or waste collection services (particularly in poorer countries and regions).

The most common forms of waste from mountaineering and trekking activities are human waste (excreta and urine), discarded equipment and supplies, and waste from pack animals. Approaches to waste management for mountaineering and trekking vary between formal measures, such as conditions placed by authorities on climbing permits or entry to national parks, through to more informal and community-based efforts to self-regulate.

Trends in mountaineering and trekking in developing regions

Case studies suggest that the number of people mountaineering and trekking has increased over the years across different mountain ranges (Lew and Han, 2015; Rassler, 2014), particularly in the developing world.

The number of foreign visitors to the Huascaran National Park (the Andes mountains, Peru) increased from 10,678 in 2011 to 48,971 in 2015, representing an almost fivefold increase in visitor numbers; compared to a 69 per cent increase in visitors to Peru over the same period. The number of hikers and climbers in Aconcagua National Park (west Argentina) has increased by about six times over the last decade, from

A trekking camp on the slopes of Mount Kilimanjaro. Photo © iStock/Apuuliworld

Definitions of mountaineering and trekking and their waste implications

There are two main types of mountaineering: alpine mountaineering and expedition mountaineering. Alpine mountaineering involves climbers carrying all their equipment and supplies with them, whereas expedition climbing usually involves setting up a series of camps stocked with provisions. Mountaineering can be distinguished from trekking, which does not explicitly involve reaching the summit of a mountain, although treks often include summits and high-altitude passes along their route.

Expedition mountaineering is most common in higher altitude locations such as the Himalayas or Andes and demands considerably longer periods of time on the mountain to allow for acclimatization. It often requires larger loads of equipment and supplies that may involve porters, pack animals, glacier airplanes, cooks and multiple transfers of provision between camps (Eng, 2010; Barros, Pickering and Gudes, 2015). Both types (alpine and expedition) have a considerable impact on the environment; however, the longer periods and greater resources needed for expedition style climbing, coupled with the remoteness and lack of infrastructure at these destinations, can mean more visible and persistent waste problems, especially at base camps.

The literature, however, does not always differentiate between mountaineers and trekkers, or other mountain tourists and visitors that also use trails and base camps.

Yaks carrying expedition kit in Gokyo Valley, Nepal. *Photo © iStock/fotoVoyager* approximately 1,000 in 1990 to around 6,000 in 2010–2011 – during the five month season from November to March (Barros, Pickering and Gudes, 2015).

The Himalayas are another popular destination for mountaineers, most notably Nepal. The Mount Everest region, along the Khumbu Valley, has experienced a dramatic rise in tourist numbers over the years, from 20 visitors in 1964 to 18,200 during the 1997-98 season (Byers, 2009), with a further increase of almost 82 per cent between 2006 and 2012 – with numbers totalling 36,518 visitors in 2012 (Nepal, 2016). In the Makalu-Barun National Park and Buffer Zone, east of Lukla, there were an estimated 800–1000 visitors for the whole of 2007; this increased to 812 for the 2012 autumn season alone, representing an almost doubling of visitor numbers (Byers, 2014). Other climbing destinations that have seen considerable increases in the number of visitors include Mount Kilimajaro (Tanzania) and Mount Kenya (Kenya).

Environmental and waste impacts of mountaineering and trekking

Some of the most common environmental impacts associated with mountain-based adventure tourism include the development and use of access tracks, campsites and refuges that lead to vegetation clearing and soil erosion, altering of landscapes and water flows, water and air pollution, wildlife displacement, the introduction of exotic and invasive species and diseases, and waste (UNEP, 2007; Pickering and Barros, 2015; Ars and Bohanec, 2010).

Trekking in Tajikistan. Photo © iStock/robas

Impacts from mountaineering can vary depending on the altitude. For instance, erosion and surface waste disposal are more visible at lower elevations below the treeline compared to higher elevation zones, where waste and pollution accumulate in water bodies and glaciers (Pickering and Barros, 2015; Welling, Árnason and Ólafsdottír, 2015). Furthermore, the extent and duration of the impact on mountain environments depends on many factors, including the number of visitiors and the seasonal and locally-specific nature of mountain-based adventure tourism, which tends to concentrate proportionaly large numbers of people into specific areas or corridors during particular times of the year.

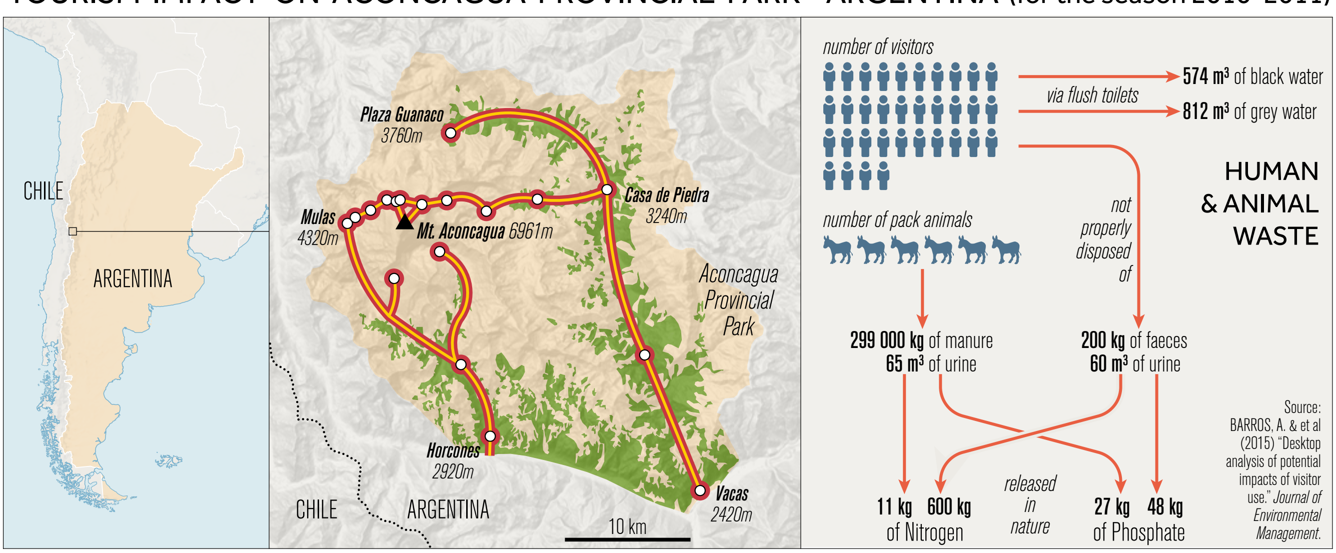
The most common forms of waste from mountaineering activities are human waste (excreta and urine), other solid waste material associated with equipment and supplies (for example, tin cans, glass and plastic bottles, food packaging, oxygen bottles, batteries, plastic bags, drums, discarded ropes and tents, pharmaceuticals, personal and cleaning products such as detergents, etc.), and waste from pack animals (UNEP, 2007). In particularly inaccessible mountain areas, bodies of deceased mountaineers are also sometimes left behind.

Human waste is by far the most cited waste problem associated with mountaineering; it is difficult to bury waste in exposed alpine environments and the extreme climatic conditions slow down decomposition (Pickering and Barros, 2015; Ells and Monz, 2011; UNEP, 2007). For example, since 1970, over 34,000 people have attempted to climb Denali (Mount McKinley, USA) via the west buttress route, resulting in an estimated 66 metric tons of faeces left in the glaciated environment (Goodwin, Loso and Braun, 2012). The bacteria, viruses and other pathogens associated with such waste contaminate waterways and soil surfaces (Derlet et al., 2008; Goodwin, Loso and Braun, 2012) and can persist in these environments despite the extreme climatic conditions (Goodwin, Loso and Braun, 2012).

These can pose immediate or short-term health risks, not only for climbers. Cases of contaminated terminus meltwater discharge have been reported also in Europe (Edwards, 2015; Goodwin, Loso and Braun, 2012). Given that many of these areas are the main headwaters for downstream users and dwellers, contamination of water sources is of particular concern (Barros, Monz and Pickering, 2015). Other types of solid waste are also an issue – as much as 140,000 kg of rubbish still remains on Mount Everest following 60 years of expeditions (Kelliher, 2014).

Waste from pack animals such as horses and mules also creates stress in mountain environments. For instance, approximately 299 tons of manure and 65 m³ of urine were produced by pack animals during the 2011 climbing season on Mountain Aconcagua. This was often deposited near water bodies in the low and intermediate alpine zones (Barros, Pickering and Gudes, 2015). Coupled with human waste, this results in an estimated 660 kg of nitrogen and 48 kg of potassium per season (Barros, Pickering and Gudes, 2015), increasing the risk of eutrophication, algal growth and toxicity of water bodies (Derlet et al., 2008). In parts of some mountain destinations, such as in the Huascaran and Aconcagua National Parks in Peru and Argentina, grazing and pastoralist activities are also permitted, adding to the environmental stress and waste issues.

TOURISM IMPACT ON ACONCAGUA PROVINCIAL PARK - ARGENTINA (for the season 2010-2011)



Alpine steppe vegetation — Tourist trail — ○ Camp site — Environmental stress due to human actions — 1 000 visitors — 1 000 pack animals

Black water: waste water and sewage from toilets ; Grey water: relatively clean waste water from baths, sinks, washing machines, and other kitchen appliances.

The southern slope of Mount Elbrus (Russian Federation) is an active tourism destination for skiers and hikers. Parts of the mountain are littered with abandoned buildings, old vehicles and other types of waste. *Photos © Ieva Rucevska*

Implementation of Waste Systems on the Inca Trail, Peru

Peru has seen a dramatic rise in tourism over the last few decades (Larson and Poudyal, 2012) and the popular tourist destination, Machu Picchu, was declared a UNESCO World Heritage Site in 1983 (UNESCO, 2016). On their way to Machu Picchu tourists can hike the scenic Inca Trail, a stone path that was built by the Incas to connect important sites throughout the Urubamba Valley.

The total number of hikers on the Inca Trail went up from 6,236 in 1984 to 130,454 in 2006 (Maxwell, 2012) with over 1,600 hikers a day using the path in the high season (July-August, 1996-2001). This drastic increase in tourism has contributed to the degradation of this historic and culturally significant path. Many trekkers camped at unregulated campsites, using the ruins as latrines and disposing of waste along the Trail.

Because of the substantial damage and UNESCO's recommendations, Inca Trail Regulations were introduced in 2002, to protect and preserve the Trail. These regulations restrict the number of visitors and prevent hiking the Inca Trail without a permit. The fee for the Trail was increased from USD 17 to USD 50 and hikers are required to trek with a registered guide (Roach, 2002; Barcelona Field Studies Centre, 2016). Today, hikes without an authorized Inca Trail Guide are no longer permitted and stringent restrictions means there is now a three-to six-month waiting list for tourists hoping to hike the Trail. Only licensed tour operators are permitted to sell Inca Trail packages and all waste must be removed from the Trail (Larson and Poudyal, 2012; Barcelona Field Studies Centre, 2016).

The Inca Trail Network of the Historic Sanctuary of Machu Picchu regulations require agencies and guides to have appropriate containers for solid waste disposal. They also require travel agencies, tourist guides and assistance crews to separate solid waste generated during their stay on the Inca Trail into organic and non-organic waste and carry it out of the sanctuary (Inca Trail, 2016).

Ecological conservation projects are held every year and the Inca Trail remains closed for one month for maintenance; no permits are issued to visitors during this time (Barcelona Field Studies Centre, 2016). In one cleaning day in February, residents of the region collected 5 tons of waste from a 10km section of the path. These measures are a positive step towards protecting the environment and managing the waste, but further studies need to be conducted to establish the quantitative benefits of these policies on the Machu Picchu region.

The Inca Trail. Photo © iStock/rest

Options for waste management

There are many different ways of dealing with human waste (urine and faeces) from mountaineers, although leaving the waste behind (buried in soil or snow, or deposited in crevasses) is still by far the most common means of disposal in remote alpine environments (Derlet et al., 2008; Pickering and Barros, 2015).

Initiatives such as the Clean Mountain Can (CMC), introduced by the American Alpine Club in 2001 in Denali led to the current policy requiring all climbers to carry and use CMCs (Rassler, 2014). The CMC is a portable toilet which is specifically designed for use on three-week expeditions. The CMCs have had some success in minimizing contamination of surface snow, although there are reports that climbers empty out the CMCs in other crevassed areas (Apollo, 2014). Another similar programme is the 'Pack it out - Poo pots' introduced in New Zealand (Department of Conservation, n.d.). Other forms of human waste removal are more expensive and resource intensive, such as fly-out systems using helicopters, as is the case on Mount Aconcagua. Fly-out systems are also commonly used in the European Alps to remove waste from refuges. There has, however, been limited success in policing and monitoring these practices. An estimated 200 kg of human faeces were left in campsites around Mount Aconcagua during the 2010/2011 summer season, representing a 10 per cent non-compliance with Park policy (Barros, Pickering and Gudes, 2015) – which requires packing up waste in bags for deposit at Park exit points.

Other solid waste, such as plastic residue and other materials are often burned in open pits or carried off the mountain and dumped in nearby landfills. However, many of the existing municipal and regional waste management facilities are basic and poorly resourced (if they exist at all), and are not designed to deal with additional solid waste; they can be filled to capacity or even overflow (e.g. Wani & Ahmad, 2013; Anand & Singh, 2014). Other issues include a lack of adequate lining (such as geo-membranes) covering the floor of these landfills; these help to contain leachate from toxic refuse such as batteries and plastics, which can pollute groundwater and subsoils.

Mountaineer carrying a green Clean Mountain Can on top of his rucksack. Photo © Coley Gentzel

Volunteers collect waste during the "Clean Alps" campaign organized by the Austrian Alpine Protection Association.
Photos © Österreichischer Alpenschutzverband

Engaging mountaineers in clean-up operations through competitions and prizes – the example of Lenin's Peak (Pamirs, Kyrgystan)

Lenin's Peak, also known as Ibn Sina, is considered one of the easiest 7000 m peaks to climb. It has also accumulated lots of rubbish as a result of climbing expeditions on the mountain. The "Keep Snow Clear" campaign,[10] which started in 2014, is one example of a voluntary mechanism for waste management involving mountaineers. It aims to remove litter from the glaciers of Lenin Peak. The campaign provides a competitive incentive for mountaineers who are attempting to climb the mountain to collect as much litter as possible, and in doing so, score points (one point rewarded for every kilogram of waste collected). All participants receive a t-shirt, and the top three point scorers are awarded presents. The campaign also offers incentives for tourist companies to participate, mainly in the form of advertising these companies alongside the campaign.

Clean-up campaigns and expeditions have also been organized to remove waste from mountains, largely led by the mountaineering community itself. One cooperative clean-up campaign on Mt. Fuji in Japan, deals with waste generated by 300,000 climbers who make a pilgrimage to the mountain in July and August each year (Rassler, 2014). Further efforts by the Park authorities to address the issue, such as installing toilets in refuges, is reportedly having positive results in reducing the impact (Permanent Delegation of Japan to UNESCO, 2016). Efforts by the Sherpa community on Mount Everest have resulted in the removal of over 900 kg of waste, including oxygen bottles, batteries and food packaging (Pickering and Barros, 2015). Clean-up campaigns are also common in Europe. For example, the Austrian Alpine Protection Association, through its 'Clean Alps' campaign, is committed to tackling waste issues in the Austrian Alps, especially in tourist areas such as Dachstein and Ötztal. Since the start of the campaign in 1970, about 3.8 million litres of waste have been collected and recycled. The campaign is supported by the local and national government as well as the private sector. In 2015, 100 cleaning missions collected 50,000 litres of waste over a three-month period.

Education and advocacy are also useful means of raising awareness of the shared responsibilities and common interest for preserving mountain environments. The International Federation of Mountain Guides Associations and other NGOs highlight the role of mountain guides as de facto environmental educators, both in providing a model for respecting the mountains and integrating environmental standards into their procedures (Rassler, 2014). Similar environmental guidelines exist for member federations of alpine clubs and associations (UIAA, 2013).

There are a variety of approaches to defining the roles and responsibilities of stakeholders (mountaineers, tour operators, public services, private services and others), which are largely context- and culturally-specific. Nevertheless, collaborative and participatory approaches for designing and implementing measures, as well as establishing a fair system for sharing the burden, are the best way to address waste management.

Experiences in developing management plans, such as the Backcountry Management Plan in Denali National Park, stress the importance of public outreach and participation in the drafting of guidelines and measures, highlighting and integrating Park visitor's experience in their metrics (Rassler, 2014). Other collaborative and participatory approaches also involve local communities in the design and implementation of measures, such as the process of designating new private conservation areas managed by local communities in the Cordillera Huayhuash in the Peruvian Andes. These proposals, to share in the conservation effort through joint management arrangements, allow local communities to help monitor and control conservation and management goals and activities, particularly in areas with increasing volumes of tourists and with little supporting infrastructure such as sanitary facilities (Bury, 2006).

The demand for the management and governance of mountaineering has evolved over time, not only as a response to larger numbers of people practising mountaineering, but also given its increased commercialization and the need to manage the many associated risks. In many mountain regions in the developing world, climbing permits, most commonly issued by local or regional park authorities, are the main means of controlling access (Cater, 2015). In some cases, environmental guidelines and regulations are issued as part of permit conditions – for example, the requirement to remove waste. However, despite significant revenues accrued as a result of these permit systems in some regions, there is little evidence of direct re-investment of these resources back into mountain protection (Pickering and Barros, 2015; Cater, 2015). In many regards, the management and governance of mountain protection largely depends on the individuals or groups that engage in mountaineering, whether commercial or amateur.

A climber on Margarita Peak, Ruwenzori Mountains, Uganda. *Photo © Kristoffer Alfthan*

From Poo to Biofuel: UIAA and the Mount Everest Biogas Project

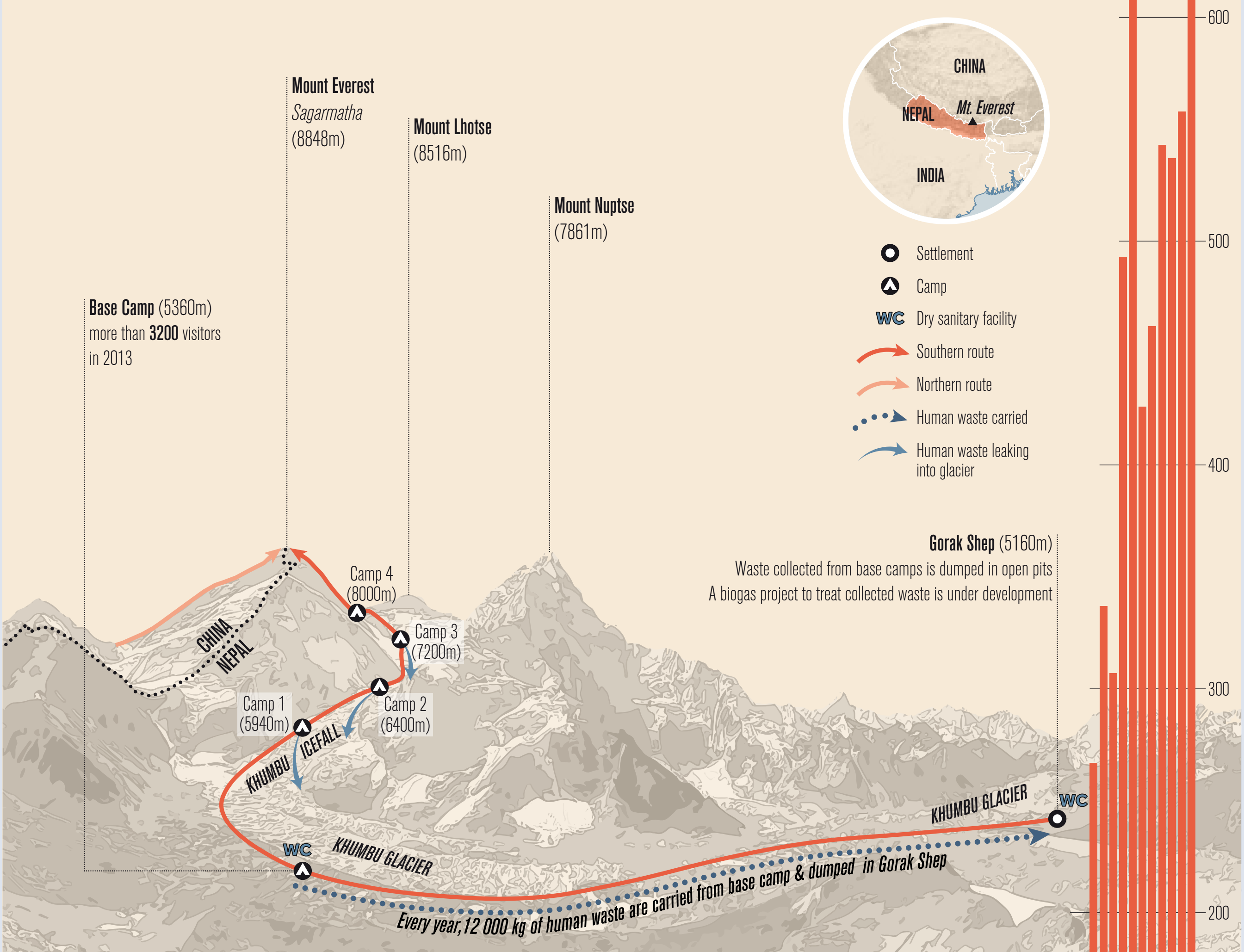
The International Climbing and Mountaineering Federation (UIAA) is the main governing body that represents and serves the mountaineering community worldwide. The UIAA's Mountain Protection Commission agrees that there is an urgent need to engage with its own community on the issue of waste. The Commission, through the UIAA Mountain Protection Award, is helping to promote the work of projects dedicated to raising awareness of waste and providing solutions.

One of the recipients of the award is the Mt. Everest Biogas Project. It addresses the issue of sustainable waste management and disposal of human waste generated by the climbing community, specifically in the Sagarmatha National Park and the village of Gorak Shep below Everest Base Camp. The project will adapt existing biogas digester technology that has been successfully implemented throughout Nepal, China, India and other countries, albeit at lower elevations and in warmer climates. To bring this technology to the extreme conditions of the upper Himalayas, the project will combine the basic design of a Nepalese biogas digester with a low technology, off-the-shelf, heating design that will allow the system to operate in colder environments. It will provide communities in the region with a form of a clean-burning, renewable energy source, as well as nutrient-rich fertilizer and local employment.

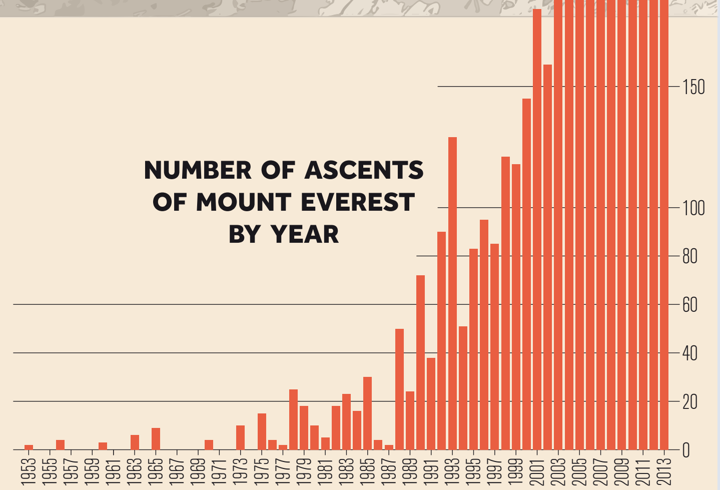
The project aims to substantially reduce the staggering 12,000 kg of solid human waste dumped at Gorak Shep every year, which includes human waste carried down from Everest Base Camp. Additional environmental benefits include a reduced reliance on open burning wood or yak dung for heating and the associated respiratory and ocular health risks; reductions in deforestation of the area's limited forest resources; and a reduced risk of water contamination. Another innovation of the project is the establishment of a primary management and decision-making group in Gorak Shep, a committee of 5-6 teahouse owners. Upon project completion, the committee will assume ownership and responsibility for the long-term operation of the biogas reactor. If implemented successfully, hundreds of other locations could learn from the experience and benefit from high-altitude biogas digesters to improve the lives of local people and their environment by reducing pollution, deforestation, health risks and the costs of alternate fuel sources.

Tents at Mountain Everest base camp.
Photo © iStock/iStock/Rafal Belzowski

THE WASTE IMPLICATIONS OF CLIMBING & TREKKING ON MOUNT EVEREST



The number of climbers attempting the summit of Mount Everest has risen drastically since its first ascent in 1953, especially from the early 1990s onwards as a result of commercialised guiding operations. Managing the increasing human and solid waste has become a major issue. The Everest Base Camp does have a waste management systems under operation, but at present there are no systems in place higher up the mountain, where climbers often dig holes in the snow to defecate or drop them in crevasses. Faeces from Camps 1 and 2 have reportedly made their way down further down the mountain along with the fast-moving Khumbu Glacier (Bishop, 2015.)



Sources: Bishop B. (2015) "Peak Poop: The Feces Problem on Everest Needs a Solution," *Outside*; The Himalayan Database, http://www.himalayandatabase.com/ ; GlaciersWorks, http://glacierworks.org/ ; Mt. Everest Biogas Project, http://mteverestbiogasproject.org

High Altitude Sustainability Pakistan

High Altitude Sustainability Pakistan (HASP) was established in 2015 to support the sustainable management of adventure tourism in the Gilgit-Baltistan region of Pakistan. It was formed by a group of committed individuals concerned about unsustainable tourism practices, the lack of suitable regulation and other activities that were beginning to adversely affect the pristine character of the area. HASP aims to support responsible tourism in the region by focusing on the entire ecosystem, which includes:

Removing physical waste from high-altitude areas by:

- retrieving at least 4,500 kg of animal carcasses and solid waste from the Baltoro Glacier a year
- segregating collected waste into metal/tin cans, paper, plastics and animal remains
- disposing metals/tin cans, paper and plastics responsibly: these are donated to locals in Skardu specializing in the recycling and reuse of waste metal or deposited at the Central Karakoram National Park incinerator in Askoli Village; animal remains are also removed from the glacier and buried in Askoli

Raising awareness by:

- staying on the Baltoro Glacier for at least 17 days a year, and engaging with tourists and at least 35 porters who regularly traverse the Baltoro Glacier (in 2015); in 2016, HASP carried out two clean-up expeditions and was present for more than 30 days in total.
- displaying banners at various campsites highlighting conservation issues.
- sharing issues and results with local traditional and social

Weighing the rubbish collected on Baltoro Glacier. *Photo © Hanniah Tariq/HASP* media. The local community is engaged at various stages during the initiative from planning to implementation. Expeditions are planned and implemented in partnership with a local Skardu-based NGO, Khurpa Care Pakistan, which has been promoting porter rights in the Baltistan region since 2005. Additionally, camp managers at various sites collect and bag up improperly discarded waste and the clean-up teams collect it on the way down to Askoli free of charge.

Providing benefits to the local porters.

- More efficient clean-up of camps and trails result in increased tourism and improvements to the local economy.
- The health of the glacier is connected to the health of porters. Water at the site is currently non-potable and porters regularly suffer from a variety of waterborne diseases.
- 35 porters receive a guaranteed expedition income.
- In addition, medical assistance is provided at all the camps set up during the clean-up expeditions. Free first aid and basic health care treatment is provided to porters for common problems faced at high altitudes. The team intends to continue this practice of free medical support in all its camps.

"We feel that an integrated approach devised by all stakeholders including the local government, NGOs currently cleaning the glacier, tour operators and porter welfare organizations is the only way forward. Our work currently is serving as a bandage but everyone needs to come to the table to ensure that individual efforts aren't being replicated and proper measures of accountability are put in place to ensure that future waste is not improperly disposed of on the rooftop of Pakistan". – Hanniah Tariq, HASP

HASP team members collecting rubbish at lower altitudes. *Photo © Hanniah Tariq/HASP*

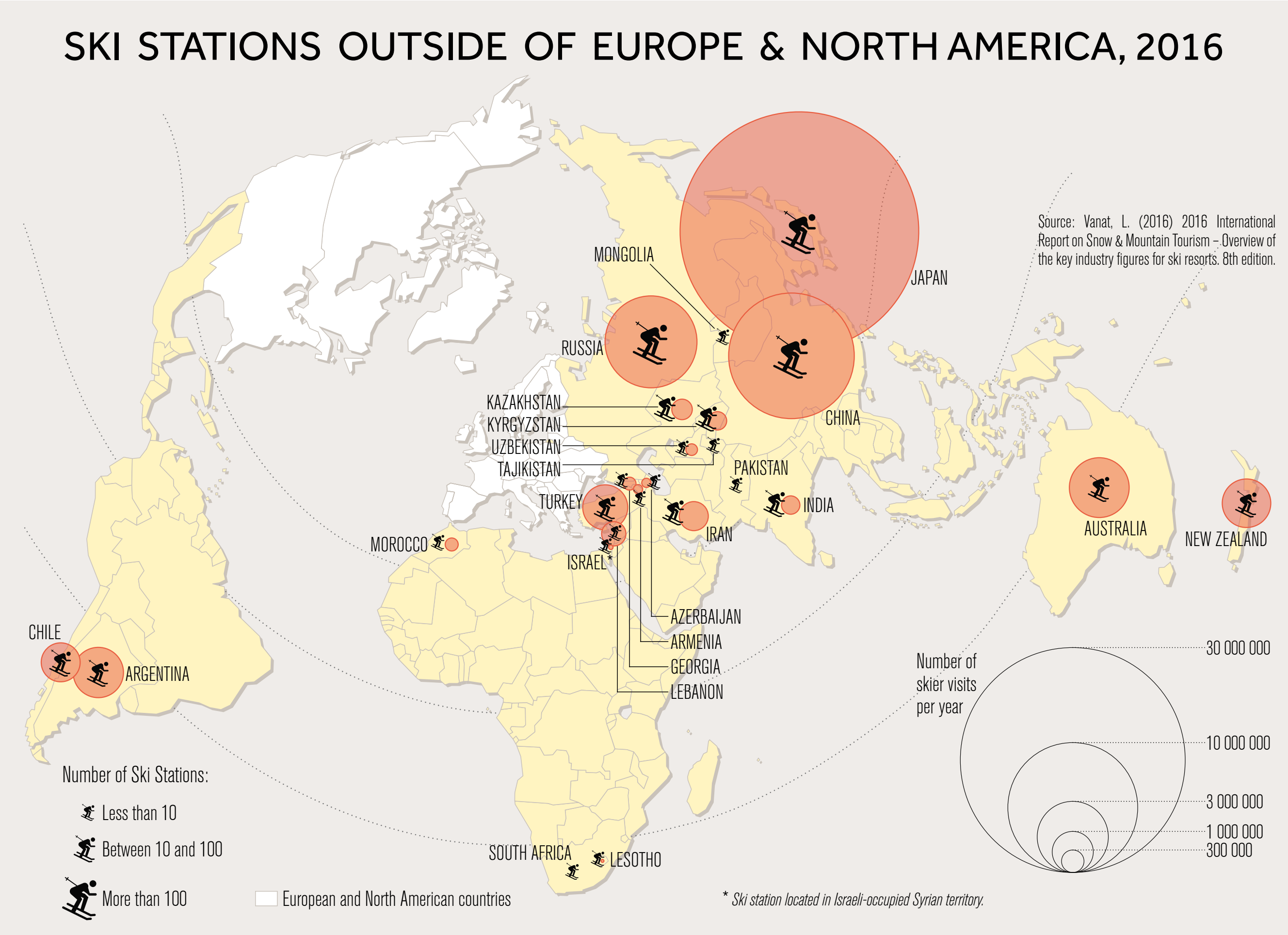
Ski tourism, winter Olympics and waste implications

Ski tourism is a winter activity attracting large numbers of tourists to Europe (particularly the Alps) and North America. Ski resorts also exist in other mountainous regions in Central and South Asia, the Caucasus, the Middle East, South America and China. Many regions are currently developing or expanding their ski industry. China, in particular, has seen a dramatic growth in the number of ski resorts as well as improvements in their quality (Vanat, 2016).

Skiing is often developed for mass tourism, which brings with it numerous waste challenges ranging from littering on the slopes, waste produced by ski resorts, to waste implications related to building and maintaining the physical infrastructure on the slopes and in resorts.

The literature on the impacts of ski tourism on the environment, and the waste implications and solutions, is largely limited to examples from the European Alps and North America. These include:

- Littering by skiers on the slopes: organic and non/organic waste is thrown along ski runs or from lifts simply because there is no waste disposal nearby (NSAA, 2005). Littering depends to a certain extent on cultural norms and practices, which can differ from region to region.
- Waste generated by ski resorts and villages, which includes the whole spectrum of organic and non-organic waste.
- The physical infrastructure in ski resorts: the construction of access roads, ski slopes and ski lifts carry with it environmental implications: deforestation, disturbance to wildlife, soil erosion and habitat fragmentation (Rixen and Rolando, 2013). The construction of hotels and buildings result in large amounts of construction waste.
- The environmental implications of artificial snow: climate change is a big threat to the ski industry because it is expected to bring warmer winters, reduced snowfall and shorter seasons (for example, Dawson & Scott, 2013; Agrawala, 2007). One solution is the use of snow cannons to create artificial snow. This practice can cause changes in vegetation (Gilaberte-Búrdalo et al., 2014) and uses significant amounts of energy and water, which is often



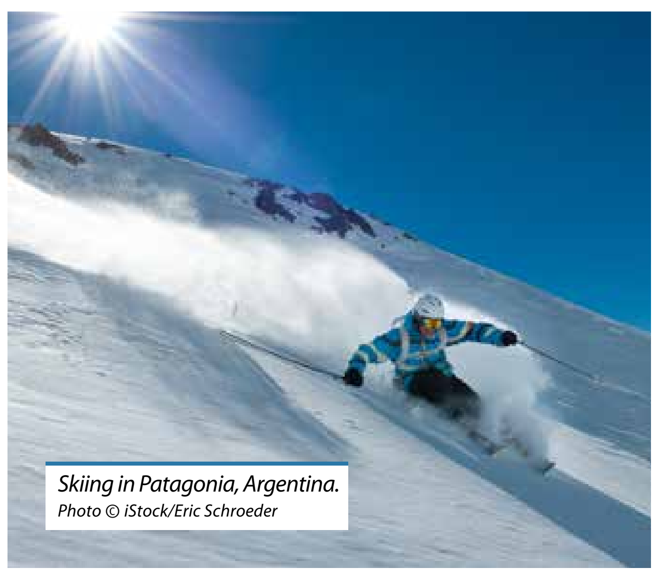
Gudauri ski resort, Georgia, South Caucasus. *Photo © Björn Alfthan*

obtained from reservoirs on the slopes or pumped up from the valley. The use of snow cannons can lead to increasing water stress and the use of groundwater resources. The practice has been criticised by environmental groups – the use of snow cannons in Switzerland is estimated to use as much water as the city of Basel during one season (SRF/Swissinfo, 2015).

- Expanding or developing ski resorts at higher altitudes: another way of adapting to decreasing levels of snow is to move or expand ski resorts to higher terrain including onto glaciers, which can further disturb fragile ecosystems (Rixen and Rolando, 2013).

Many ski resorts have made efforts to reduce waste and make their operations more environmentally friendly. The Sustainable Slopes Program, for example, is a voluntary environmental initiative in North America which encourages ski resorts to reduce, re-use and recycle waste as well as tackle potentially hazardous waste (NSAA, 2005). The Whistler Blackcomb ski resort in Canada is striving for zero-waste through an approach which combines responsible purchasing, re-use and recycling.

Organising and building venues and related infrastructure for major winter sporting events, such as the winter Olympics, also may carry waste implications, especially where there is little existing infrastructure and the timeframe for completion is short. Sochi's candidature to host the 2014 Winter Olympic Games contained a "Zero Waste System" which included the process of converting waste into energy and building supplies. Despite this promise, illegal dumping and especially construction waste dumping took place prior to and after the games on a significant scale (Sobol, 2015).



Skiing in Patagonia, Argentina.
Photo © iStock/Eric Schroeder

Mining at Altitude

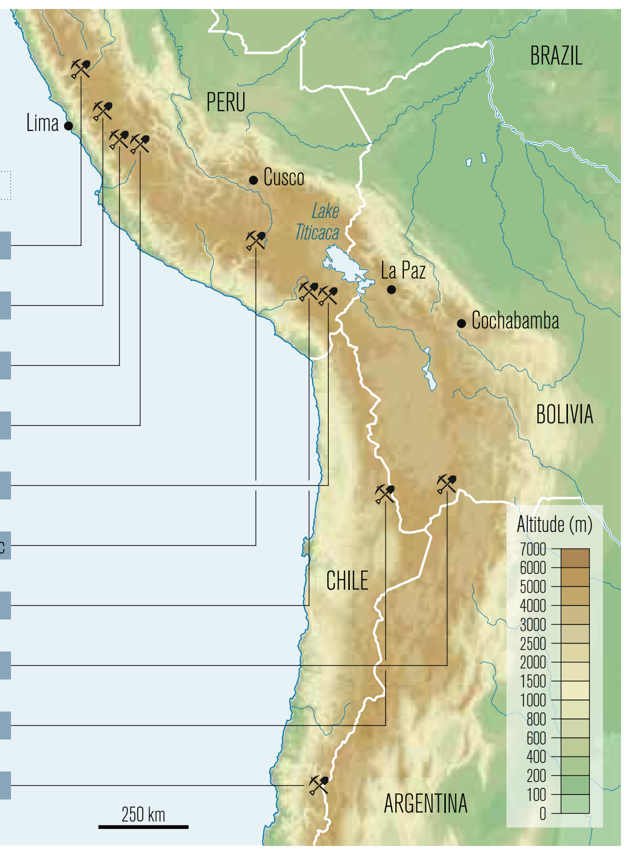
The same geological processes that have created the mountains of the world have also produced rich mineral belts including gold, copper, zinc, lead and coal. Today, mining is the most common heavy industry within mountainous regions of developing countries and includes a diverse range of operations and final products.

Mining activities produce waste that can have serious impacts on the health and well-being of people and the environment. These impacts may continue for long after the mine has closed and any benefits exhausted (so-called legacy issues). Managing large amounts of mine waste is challenging in any environment, but is made especially difficult in mountain regions, where steep slopes, terrain instability, seismic activity and adverse weather conditions add another level of complexity and risk to mine safety and waste management.

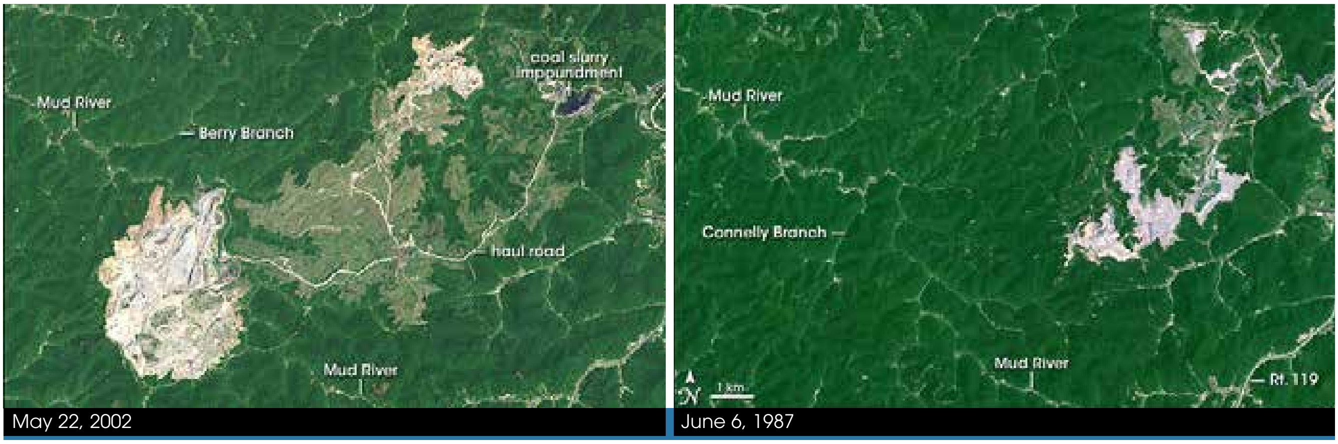
Developing a mine, in what are often remote areas with limited infrastructure, difficult terrain and extreme climatic conditions can bring unique challenges. Waste is not only generated from the excavation and extraction of the mined material, but large amounts of waste rock and soil can be produced during the initial development of the mine and associated infrastructure. More complex waste is produced by the mining community itself, any processing of the ore that occurs on site, transport of mined material and the natural hydrological and chemical processes that act on the disturbed terrain (including after the mine has closed).

SOUTH AMERICA'S HIGHEST ALTITUDE MINES

Altitude	Mine	Country	Type of mine	Minerals
4800 m	**Raura**	PERU	Open-pit and underground	Copper, Lead, Silver, Zinc
4800 m	**Toromocho**	PERU	Open-pit	Copper, Molybdenum, Silver
4800 m	**Solitaria**	PERU	Underground	Copper, Lead, Silver, Zinc
4800 m	**Corihuarmi**	PERU	Open-pit	Gold
4850 m	**Santa Rosa**	PERU	Open-pit	Gold, Silver
4850 m	**Caylloma**	PERU	Underground	Copper, Gold, Lead, Silver, Zinc
4950 m	**Acumulacion Mariela**	PERU	Open-pit	Gold
4950 m	**Bolivar**	BOLIVIA	Underground	Lead, Silver, Tin, Zinc
5000 m	**Aguilucho**	CHILE	Open-pit	Copper
5000 m	**Pascua-Lama**	CHILE	Open-pit	Copper, Gold, Silver

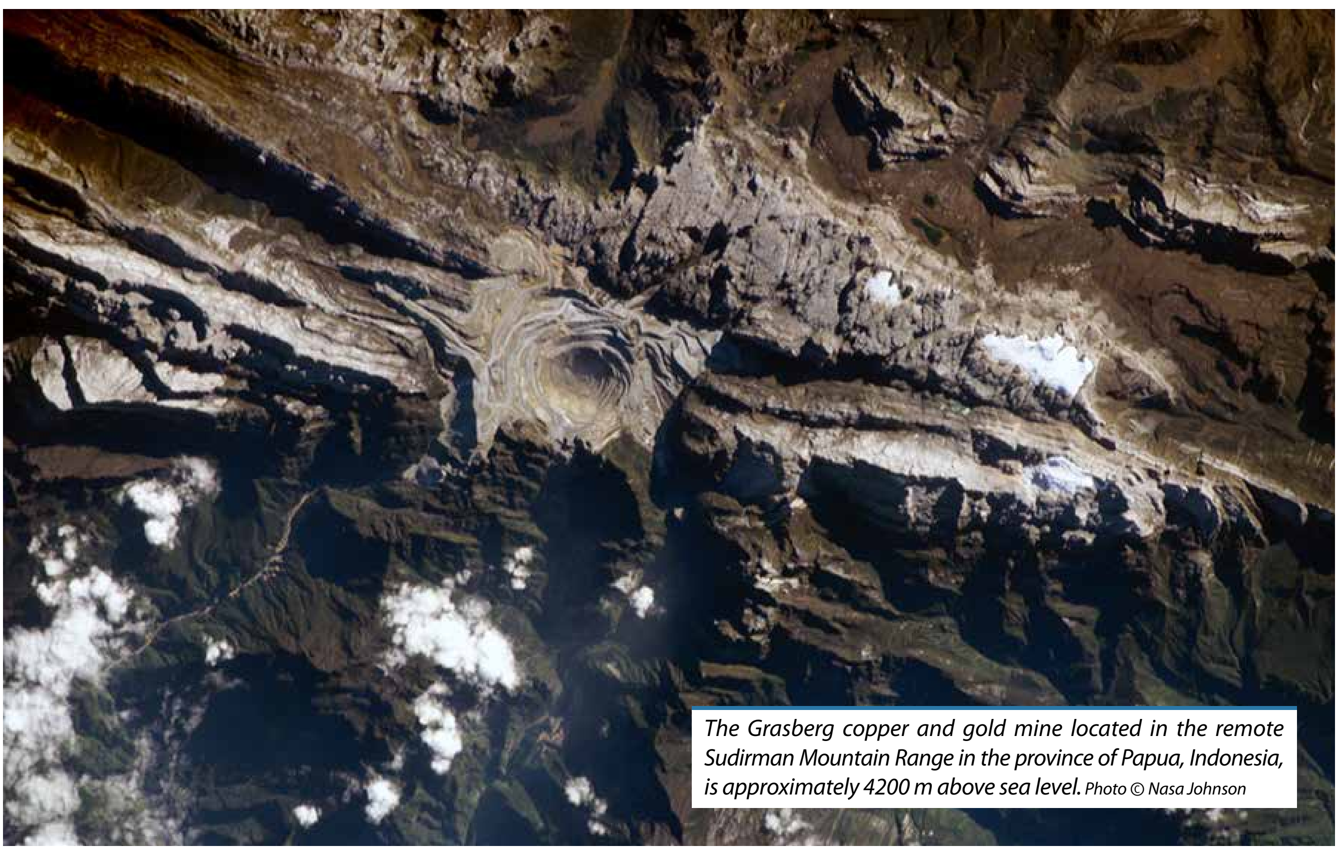


Source: www.mining.com



A comparison of coalmine area (1987 to 2002) in the Appalachian Mountains (United States) showing the extent of land clearing and road development associated with the expansion of the mine. *Image NASA Earth Observatory/Jesse Allen/University of Maryland's Global Land Cover Facility*

Poorly managed waste generated in mountain areas can move downslope, transported by water or sediment (a mechanism that is sometimes intentionally used to dispose of mine waste – see Ok Tedi case study). This means that mountain mines and associated communities have the potential to expand their waste footprint to areas very distant from the original waste source. Containing mine waste against the forces of gravity is expensive and requires careful management, planning and monitoring. Transporting community waste to lower elevations for processing or disposal is sometimes required, which also involves resources and planning.



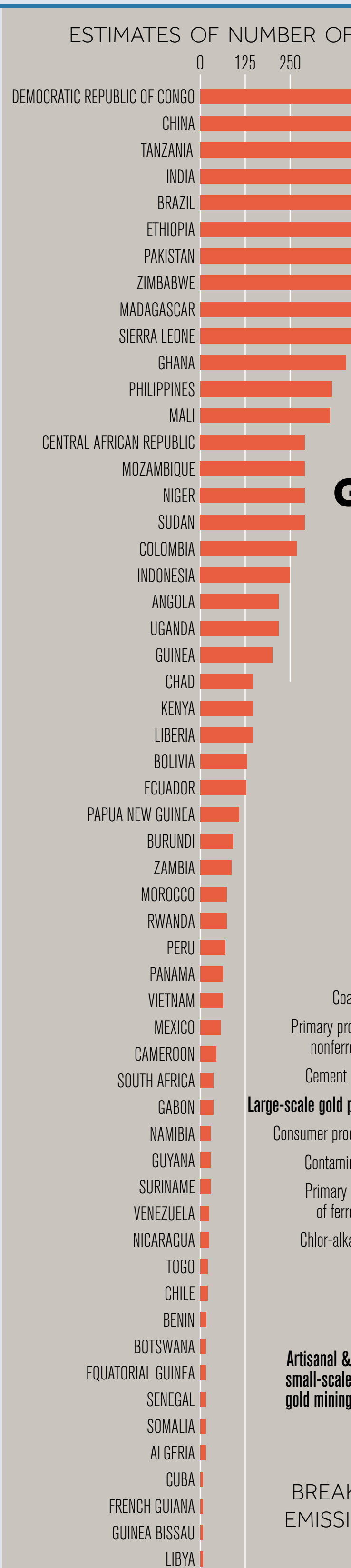
The Grasberg copper and gold mine located in the remote Sudirman Mountain Range in the province of Papua, Indonesia, is approximately 4200 m above sea level. *Photo © Nasa Johnson*

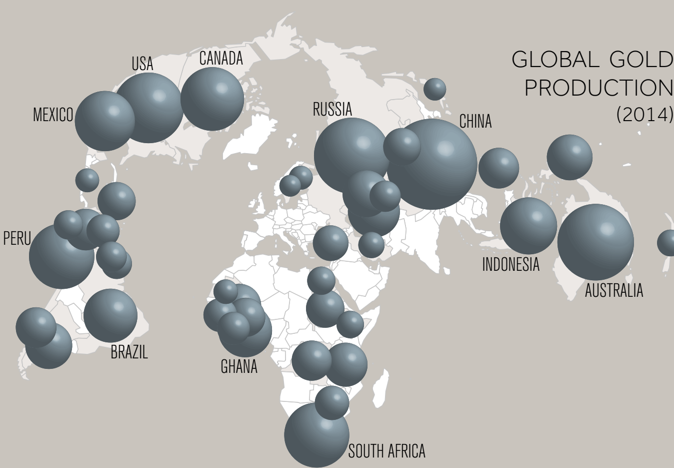
The highest inhabited village in the world is a mining village

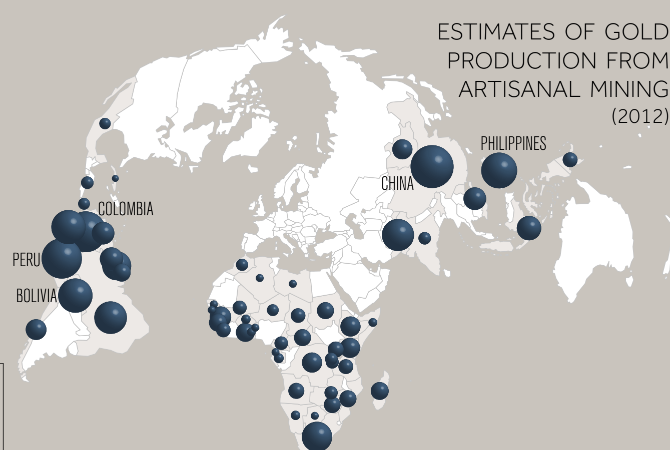
La Rinconada is a town that clings to the side of a mountain in southeastern Peru. At 5100 m it is famous for being the highest settlement in the world, but it is also becoming increasingly well known for being one of the most dangerous places to live. Estimates of the population vary between 30,000 and 50,000 inhabitants, all of whom are there because of gold - people have been mining gold in the mountains since the Incas (Wade 2013, Finnegan 2015). Despite the large population there is no sewage system, no organized waste management, no running water and no paved roads (Arana 2012). The people are desperately poor despite the area yielding more than $400 million worth of gold a year (Arana 2012). La Rinconada is not a company town built to service an international mining operation, instread it supports informal unregulated mining that relies on mercury to process the gold. The miners dig ore from the mountains and then grind it, adding mercury to form a gold – mercury amalgam. They dump the contaminated waste water and sediment. The amalgam is then taken to one of the more than 250 gold shops in the town, where it is heated to release the gold. The process is inefficient, sending mercury vapour into the atmosphere, which aided by the cold eventually precipitates adding to the load of mercury entering waterways (Fraser 2011). A study of the air quality in and around La Rinconada's gold shops, suggested that they could be emitting as much as 20 metric tons of mercury per year (Wade 2013). Information on the impact of mercury exposure to the community is lacking, but there is ample evidence from other artisanal mining communities that these high levels of mercury will be causing widespread irreparable health problems to both children and adults, including neurological, kidney and possibly immunotoxic/autoimmune effects (Gibb and O'Leary 2014).

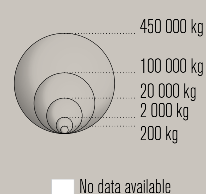
Miners heading up to the La Rinconada tunnels in the high mountains tramp on polluted slush flowing from the mines and pass mounds of rubbish. Photo © Gina Nemirofsky

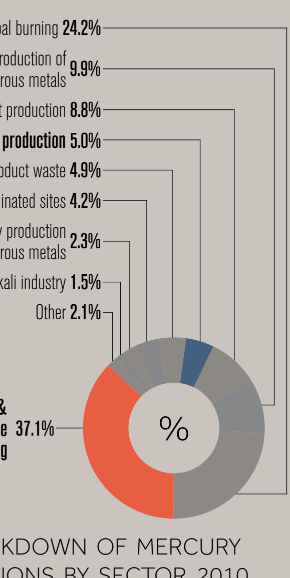
ARTISANAL GOLD MINING & MERCURY EMISSIONS











Source: UNEP (2013) *Global Mercury Assessment 2013: Sources, Emissions, Releases and Environmental Transport*, Switzerland: Geneva. Seccatore J. and et al (2014) "An estimation of the artisanal small-scale production of gold in the world," *Science of The Total Environment*, 496. World Gold Council (2015) Interactive gold mining map, http://www.gold.org/

Moving mountains to build a mine: Waste generated from clearing the site and infrastructure development

Before the mine operation starts the site needs to be prepared and an access road constructed. This often involves significant land clearing and in mountain regions the waste rock and soil is often just bulldozed downslope, where it can block natural watercourses. The large areas of disturbed land and earth exposed can also lead to substantial erosion and increased sediment loading to waterbodies, especially during periods of high rainfall and snow melt. The building of roads and development of the mine brings heavy, generally diesel-fueled machinery, which can also cause local air pollution from diesel particulates and dust generated during operation.

Apart from the obvious destruction of habitat, land clearing and road building has been found to open up previously inaccessible regions to hunters, increase road kill numbers, especially of slow moving ground dwelling species and increase species invasion (Laurance et al 2009). Upslope activities can increase runoff that flows to and degrades soil on downslope areas which may include agricultural land. The development of the Hidden Valley gold and silver mine in Papua New Guinea impacted downstream communities during the construction phase (2006 to 2009). People living below the mine complained of increased sedimentation, poor water quality and health issues related to erosion of waste rock disposed of on steep slopes (Mudd and Roche 2014). Disputes over compensation for the damage took several years to resolve (UNDP 2014).

Mining attracts people: Waste generated by the mine workers and associated community

Mining operations require a work force and depending on the size of the mine, a considerable community can spring up in previously sparsely inhabited areas. For example, the Ok tedi mining township of Tabubil, in the Star Mountains of Papua New Guinea currently supports more than 30,000 inhabitants in what was once the tribal homelands of about 700 local indigenous people (Townsend and Townsend 2004). The rapid growth of mining camps and towns can bring problems with sewage and waste disposal. A recent study by researchers from Columbia

Mining trucks. *Photo © iStock/erlucho*

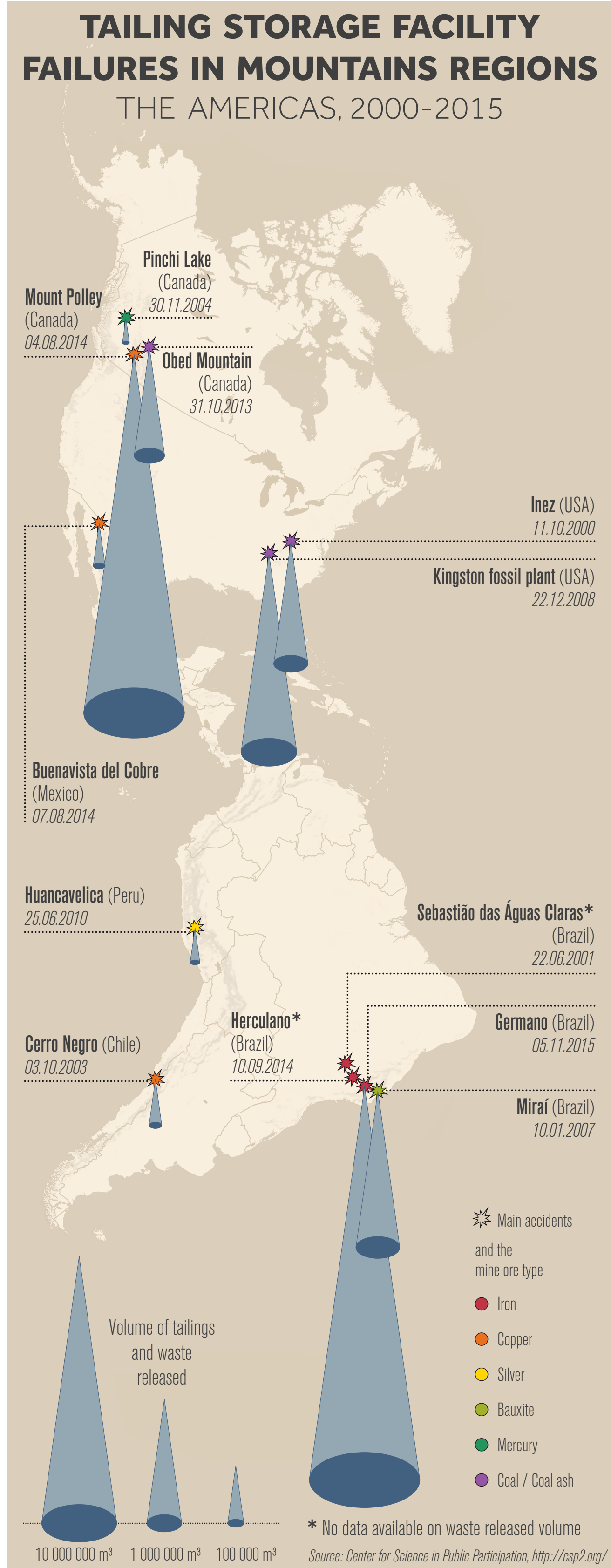
University described the villages around the Porgera gold mine in Papua New Guinea as poverty-stricken, over-crowded and unsafe. Many communities experience water shortages and poor sanitation with limited waste management options. The problems are exacerbated by a continual influx of people from surrounding areas seeking economic opportunity (Fisher 2016).

The waste issues faced by the camps that proliferate around large scale industrial mining operations are also apparent in the communities associated with small scale and informal mining in remote mountains areas. Artisanal mining is often the only available source of livelihood for communities in gold or gem rich mountain areas. Former farmers turn to mining and flock to shanty towns that spring up following the rush to wealth and in these towns waste management is a low priority. The gold mining camps that have been established high in the Andes near the border between Peru and Bolivia are an example. In 2015 Peruvian police went to Ananea and destroyed 18 of these camps and the heavy machinery used by the thousands of miners living there. This was reportedly undertaken to protect the catchment of Lake Titicaca, the largest freshwater body in South America, from mercury and other waste originating from the mines (A/P 2015). Earlier this year Peruvian police ventured into the mountains further north and destroyed 15 mining camps in the Huascarán National Park (a UNESCO recognized biosphere reserve). These miners were excavating for zinc and lead (Mann 2016).

Mining above the clouds: Waste generated from the extraction and processing of the ore

Mining activities have the potential to produce large amounts of hazardous material. Mining wastes consist of solid, liquid and gaseous waste. The solid waste includes mine tailings which, along with overburden, are generally the most voluminous waste produced at mine sites. They are also the most likely source of serious environmental damage.

The composition of the tailings depends on the nature of the host rock, the material being mined and the processing method. Following extraction, the ore is processed to concentrate the minerals. Processing may include, crushing, washing (which can require large amounts of water) and chemical treatment. The waste from processing, referred to as tailings, consists of ground rock, uneconomic metals and water that contains unrecovered processing reagents and chemicals. Tailings are generally discharged as a slurry and retained on site in dams, impoundments and banks. In some instances, they are still intentionally disposed of into valleys and waterways (a practice generally restricted to developing countries; see Ok tedi case study).



Mountain-top Coal Mining

Removing the tops of mountains is a coal mining method that is widely practiced in the Appalachian Mountains of the United States. Prior to the 1970's coal in the area was only mined underground, but now surface mining, that brings down mountains, makes it profitable for companies to mine seams of coal that were once too shallow or too thin to be viable (Bernhardt et al 2012). Generally, between 150 and 250 meters of the mountain top is removed to access the coal. It's a method that produces huge amounts of waste – it is estimated that for every ton of coal 16 tons of overburden (waste rock and soil) are removed (McQuaid 2009). This waste is disposed in a controversial process known as valley fill. In 2012, Bernhardt and Palmer (2012) estimated that valley filling had buried over 2000 km of stream channels in the Appalachians.

But overburden is not the only waste produced at mountain top mines. The coal is washed prior to shipment, to remove sulphur and other impurities, including clay and rock, leaving behind a contaminated slurry that contains known carcinogens (Epstein et al 2011 and refs. therein). This slurry is stored in impoundments or sometimes injected into abandoned underground mines. The more common impoundments are generally constructed by building a wall of coal waste across a valley to create a dam (OSMRE 2015). The Appalachian region has many of these dams. In West Virginia alone, there are more than 120 containing over 100 billion gallons of coal slurry (Epstein et al 2011). There are regular spills and leakages from the impoundments – one of the largest occurred in 2000 when the Massey Energy-owned sludge dam broke releasing more than 300 million gallons of slurry into underground mine shafts (Eades, 2000). The sludge flowed from the mine openings, heavily contaminating local creeks and rivers (Scott et al 2005). Studies have also confirmed that leaking coal slurry from underground storage locations can contaminate water supplies (Eckstein 2011).

A review of the impacts of mountain-top mining in the Appalachians by Palmer at al (2010) reported reduced stream biodiversity and water quality, including elevated pH, and increased concentrations of metals including selenium and increased sulphates below valley fills. Increased surface runoff was also responsible for an increased frequency and magnitude of downstream flooding. Studies by the United States Geological Survey (USGS) also suggest that even after mine remediation, domestic wells in mined areas have higher levels of potentially toxic mine-derived chemical constituents than well-water from unmined areas (McAuley and Kozar 2006).

In 2014 Appalachian coal companies started to file for bankruptcy as the coal price fell due to the emergence of cheaper coal seam gas. In 2015 one of the biggest coal companies in the world, Alpha Natural Resources, the operator of dozens of mines in the region, joined them (CBS 2015). Alpha has since emerged from bankruptcy, but the failure of companies and continuing uncertainty in the industry leaves the mountains of waste and the communities living with them in an increasingly vulnerable position.

The top has been blasted off this mountain ridge in South Western Virginia and a large dam constructed to store sludge waste. Photo © OVEC/Vivian Stockman

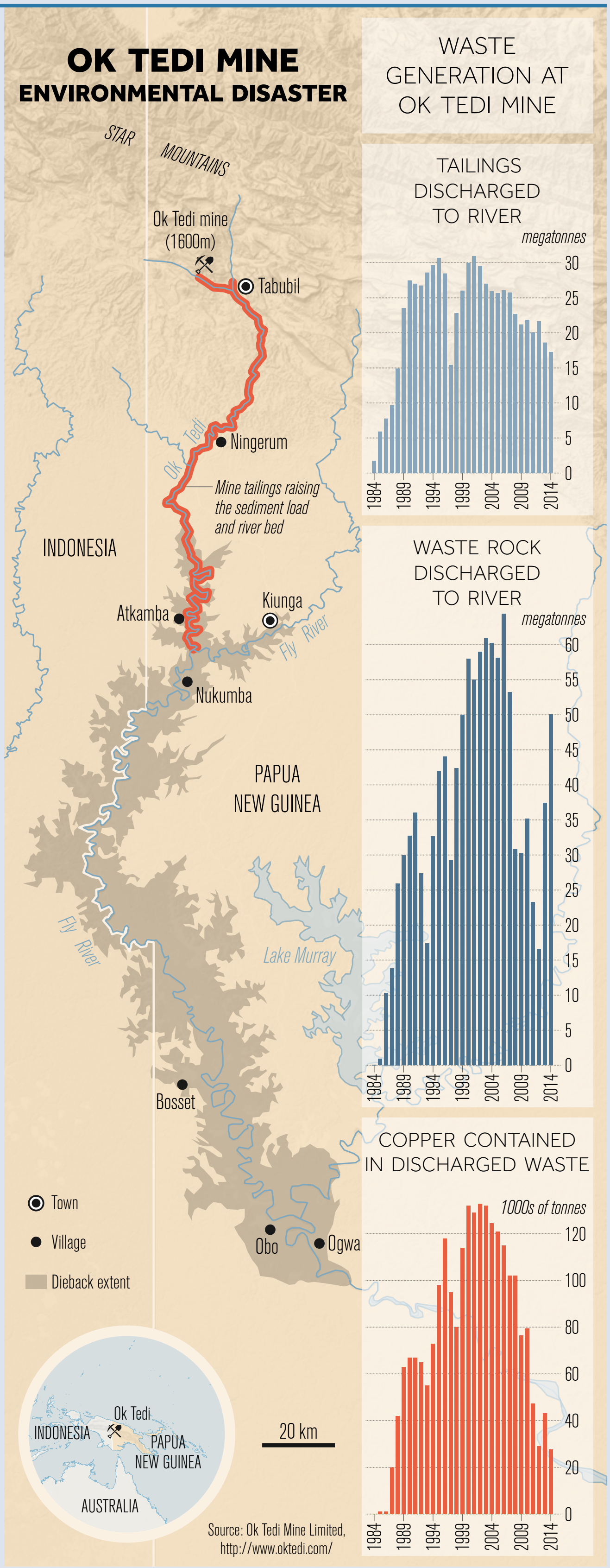
Ok Tedi Mine, Papua New Guinea

The Ok Tedi mine, one of the largest copper mines in the world, demonstrates the difficulty of waste management in mountain environments and the impact mine waste can have on downstream people and ecosystems. The Ok Tedi mine is located high in the Star Mountains of western Papua New Guinea. The area is subject to extreme rainfall (exceeding 10 m/yr) and is in an active seismic zone (Eagle and Higgins, 1991). A tailings dam was originally planned for the mine, but during the construction phase in the late 1980's, it collapsed and the company was given permission to go ahead with an alternate waste management plan. A crude, low-cost option consisting of erodible dumps was employed – essentially waste is dumped on steep slopes designed to erode into the headwaters of the Ok Tedi River, a tributary of the Fly River.

The annual discharge into the Fly River is estimated to about 65 million tons per year (OTML, 2014). This increased sediment load has had a major impact on downstream communities, severely affecting the riverine and flood plain environment. It has raised the riverbed, in places dangerously accelerating currents and caused extensive areas of forest dieback due to sedimentation in the flood plain (Baker 1999). Ok tedi Mining limited, the operators of the mine, have estimated the dieback area could eventually be 3000 km^2 (Van Zyl et al 2002).

It is thought that more than 30,000 people have been directly impacted by the mines' operations (Banks, 2001). Elevated levels of copper (highly toxic to many aquatic organisms) have been implicated in the decrease in fish stocks in the river (Swales et al 1998). Increased levels of copper and other mine derived contaminants have been detected in the Fly River Delta more than 1000 km downstream from the mine (Baker, 1999).

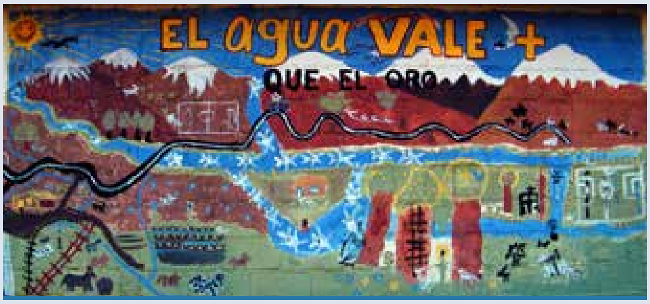
The potential long-term consequences of the waste disposal strategy, including any future provision for cleanup, were a major factor in the decision of the original owners of the mine to depart in 2002. The mine is now owned by the PNG government (OTML, 2016) and the people of Papua New Guinea have inherited sole responsibility for the waste problem. A fund has been set up (the Ok Tedi Foundation) to provide long term development assistance and compensation to the villages impacted by the mine (WRI, 2003).



Mining, glaciers and water supply: The controversy of the Pascua-Lama Gold Mine

The Pascua-Lama Gold Mine, located on the border between Chile and Argentina at about 5000 metres, has seen significant controversy since operations began in 2005. The mine is located within a biosphere reserve, which contains large glaciers that provide water needed by 8500 farmers in the Huasco Valley. Construction of the mine is thought to have affected glacial melting patterns and water quality, and has led to prolonged legal battles and petitions against the mine's owners, Barrick Gold (ECC Platform, 2015). In 2013, the Chilean Court ordered the suspension of construction at the mine until adequate measures were put in place for water management, finding that the company had 23 violations of its environmental impact agreement (A/P, 2013).

That same year, the farming communities in the Alto del Carmen region together with the Latin American Observatory of Environmental Conflicts (OLCA) filed a lawsuit against Barrick Gold, alleging that dust from the mine settled onto and accelerated the melting of these glaciers. However, in 2015, Chile's environmental court rejected claims that the mining project damaged the glaciers, although the NGO who filed the lawsuit in question accused the government of ignoring scientific documents produced by state scientists, in favour of scientists hired by Barrick Gold (GlacierHub, 2015; OLCA, 2015).

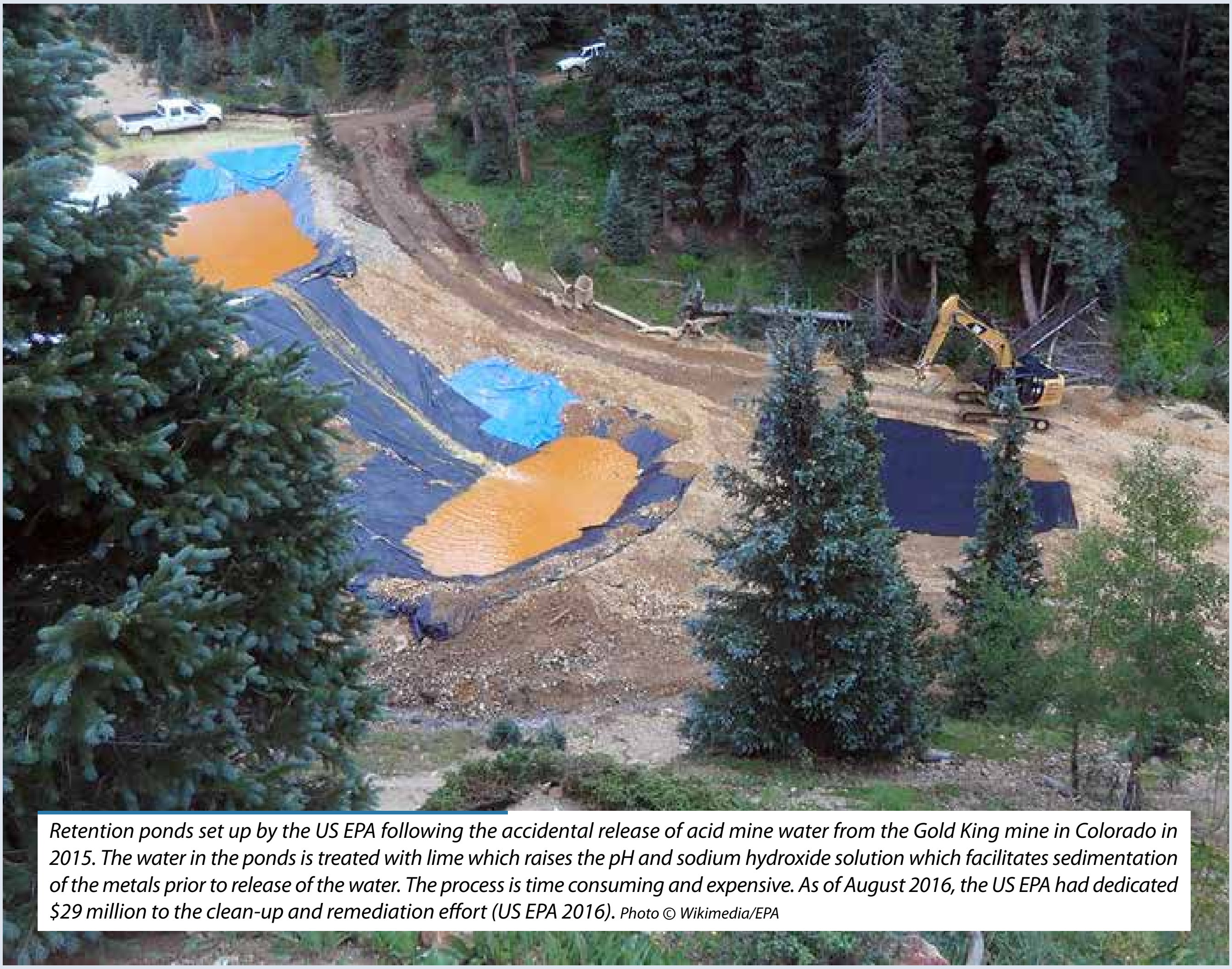


A wall painting referring to Pascua-Lama. Photo © Flickr/Amilcar

Acid mine drainage in mountain areas – a slow motion environmental problem

The Gold King mine, located in the San Juan Mountains of Colorado, last operated in 1922 but has been in the news in recent years due to an unwanted legacy that had been slowly building up in the abandoned gold and silver mine. The legacy was acid mine drainage. In 2015 officers from the United States Environmental Protection Agency (EPA) investigating a slow leak at the mine entrance, accidently released 3 million gallons of this toxic material (Chief et al 2016). Much of the contaminated water and sludge flowed into the Animas River, the upper reaches of which were already adversely affected by decades of slow seepage of acidic water from the mine. The Animas River flows into the San Juan River and ultimately into the Colorado River (traversing 5 states - Colorado, Utah, New Mexico, Arizona, Nevada, and California).

The sudden release of large volumes of toxic material, that included lead and arsenic, had a widespread impact that extended far downstream, disrupting the drinking water supply of towns and halting recreational activities and irrigation of crops leading to heavy crop failure. The impact of the acid mine drainage on water quality and river bed sediments appears to have been fairly short lived (the Animas River had poor water quality pre-spill) as snow melt helped to dilute the river water and wash away contaminated sediment (Cohen 2015). However, the spill had serious financial consequences for many people, due to tourism and agricultural losses. As a consequence, many states and individuals are suing the EPA for damages (Roberts 2016).



Retention ponds set up by the US EPA following the accidental release of acid mine water from the Gold King mine in Colorado in 2015. The water in the ponds is treated with lime which raises the pH and sodium hydroxide solution which facilitates sedimentation of the metals prior to release of the water. The process is time consuming and expensive. As of August 2016, the US EPA had dedicated $29 million to the clean-up and remediation effort (US EPA 2016). Photo © Wikimedia/EPA

The 2015 dam collapse at the Germano iron ore mine in Brazil flooded the village of Bento Rodrigues killing 19 people and spreading toxic red mud for more than 700 km. *Photos © Wikimedia/Rogério Alves/TV Senado*

Tailings stored in dams and impoundments are theoretically supposed to remain forever, but in reality many storage facilities fail. When mines were small-scale operations, the storage of tailings was not given a lot of consideration and waste was stored poorly or just dumped into valleys or rivers (and there are many old abandoned mine sites that cause environmental damage today as tailings do not necessarily become “safer” with time). Improved technology has made it economical to mine progressively lower grade ores, resulting in larger mines and the production of more and more tailings that need to be permanently quarantined from the environment. A review of major tailings dam failures in the period 1910 to 2010 by Bowker and Chambers (2015) found a trend towards failures of increasing magnitude and negative impact, and concluded that the scale of future disasters could require cleanup operations that were beyond the economic capacity of mining companies.

Some of the largest mines in the world, and consequently the largest waste dumps, are found in mountain regions and statistically it appears that some of these storage dams will fail in the future (Morgenstern et al 2015). The 2015 dam collapse at the Germano iron ore mine located in ranges of Minas Gerais in southeastern Brazil, illustrates the social, environmental and economic impact of a giant dam failure. The collapse flooded the village of Bento Rodrigues killing 19 people and spreading toxic red mud for more than 700 km across two states (Hatje 2016). If a failure of this magnitude occurred high up in the mountains the consequences could be even more devastating and geographically extensive.

Perpetual waste: Waste generated after the mine has closed

Mine restoration in mountain areas is difficult due to the steep slopes, often thin, poor topsoil and high intensity rainfall events. In addition, disturbed areas can be very extensive - open pit mines constitute some of the largest man-made structures. Some mine sites are just abandoned, with no attempt at restoration – this is especially common in areas that have experienced informal mining, in developing countries and or mines in developed countries that operated prior to effective environmental legislation. Without restoration, abandoned mine sites experience long-term erosion and leaching from tailings impoundments and waste rock dumps. Hard rock mines (associated with ores containing sulphides and minerals like gold, silver, iron, copper, zinc, nickel, tin and lead) can also be a source of environmentally damaging acid mine drainage.

Long after the economic minerals have been exhausted, acidic waste can still be generated from the mine, stored tailings and exposed rock. When iron sulphide minerals, common in many mineral deposits, are exposed to air and water, they react to form sulfuric acid and dissolved iron (the iron can precipitate, forming

Examples of some existing best practice guidelines, documents and initiatives related to mining waste

“Reference document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities”: In 2009, after an accident in Baia Mare (2000), Romania, the European Commission released this document, which as the name suggests describes best available techniques for mining of the metals, coal and selected industrial minerals. It includes rock-waste management and tailings management (European Commission, 2009)

“Safety guidelines and good practices for tailings management facilities”: The United Nations Economic Commission (UNECE) for Europe issued this report in 2010 to supporting policymakers and the business sector in enhancing awareness and the sharing of experience and good practices among the competent authorities, operators and the public. Another aim of this document is the better harmonization of the regulations and requirements concerning the safety of tailings management facilities (TMF) in the ECE region (UNECE, 2014)

“Best Practice in Environmental Management of Uranium Mines”: the International Atomic Energy Agency (IAEA) released this document in 2010 with the objective to provide both operators and regulators with guidelines and examples of the implementation of the principles of best practice to the uranium mining and processing industry. (IAEA, 2010)

International Council on Mining and Metals (ICCM): ICMM is an international organisation whose goal is to improve the social and environmental performance of the mining and metals industry. ICCM brings together 23 mining and metals companies and 34 regional commodities associations, identifying common challenges and working to establish a safer and more sustainable industry. (ICMM, 2016) characteristic red, orange or yellow sediments, USGS 2016). As a consequence, the natural drainage water that flows on and below the surface becomes acidic and can dissolve heavy metals, such as copper, lead, zinc, cadmium and mercury that occur in the rocks and tailings. The contaminated ground and surface water makes its way into downstream waterbodies and both the acidity and dissolved metals can have serious downstream impacts on people and ecosystems.

Regulations and frameworks for mining waste

Management of mining waste has improved over the years as a result of regulatory and legislative pressures (Peck et al., 2005). After several incidents and severe accidents in both developed and developing countries, governments and international organisations decided to build a technical framework for mining activities. Countries, international organisations and agencies have drafted technical documents related to best practices for the mining industry (mainly for the management of mining waste). The challenge ahead is to make mining companies liable for the post mining period.

The level of mining industry compliance to regulatory norms depends on several factors, including:

- presence of a legislative and regulatory framework (which can include "self-regulation) by companies themselves
- existence of an efficient enforcement system
- pressures from the civil society (such as affected communities)

The existence of a coherent legislative and regulatory framework within a country is a necessary condition but it is not sufficient to ensure environmentally sound waste management and health and safety systems. Guidelines might be helpful but do not guarantee that the mining company will observe them during the life cycle of the mine.

It is important that an enforcement system is in place to ensure that industry complies with the national regulations. Participation of civil society in the permitting process also can be helpful for the identification of some potential non-compliance problems which could remove them from the early stages of the activity. Civil society pressure can also be a driver for self-regulation, where an industry establishes codes of practice, enforcement or other mechanisms for regulating itself.

Accidents can happen even if a company is observing all regulatory and guiding technical norms, but if the activity was not properly designed and operated (waste management planning and operation, health and safety observed) sooner or later the accidents would appear. Unfortunately, these accidents cause serious environment damage and can lead to the loss of human lives.

Emerging Issues

Natural Disasters and Waste

Plastic Pollution and Downstream Impacts

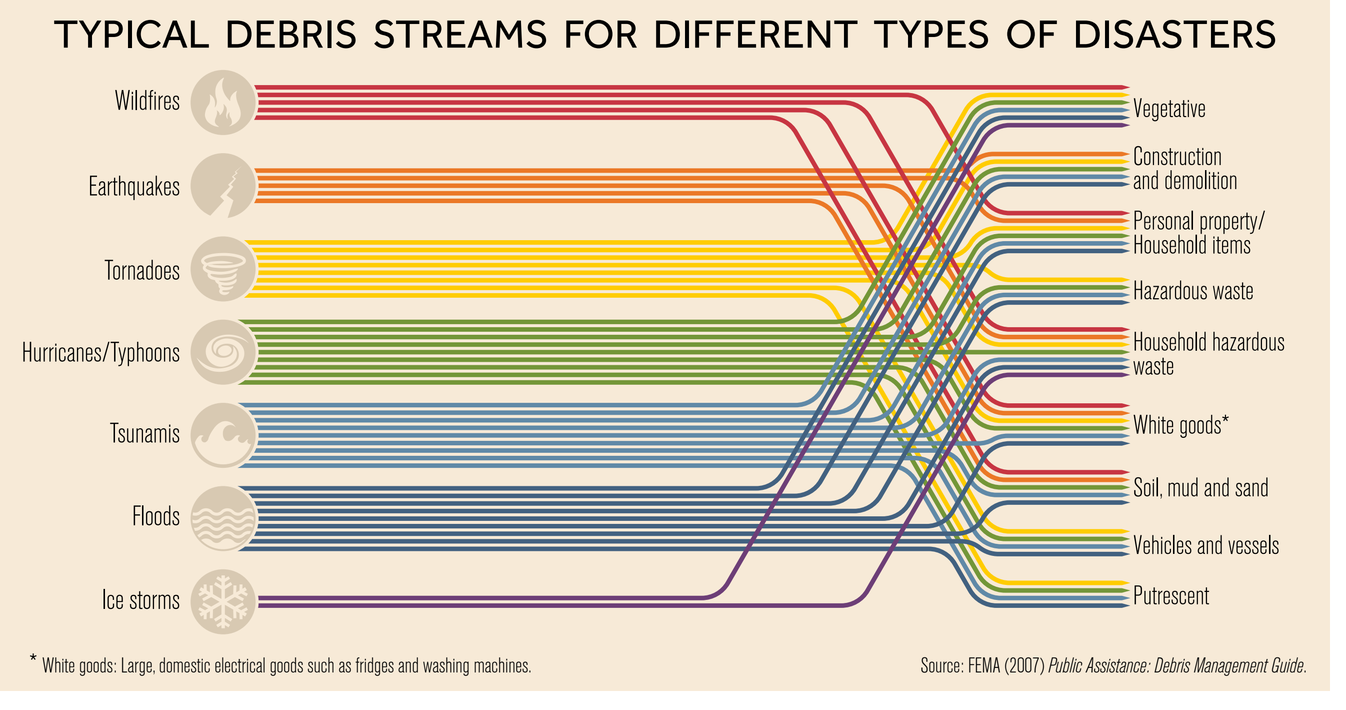
Waste Crime

Natural Disasters and Waste

Mountains are prone to natural hazards, such as avalanches, extreme weather, landslides, glacial lake outburst floods, floods and earthquakes. Mountain areas are by their very nature, mostly located in seismically active areas (mountain-building is a result of the geological process of plate tectonics). In the Andes, for example, about 88 per cent of the mountains are susceptible to earthquakes (Kohler and Maselli, 2009). Mountain communities living on steep, unstable terrain or along steep river valleys, as well as downstream communities, are particularly vulnerable to natural disasters because of their high degree of exposure and their low coping capacity (due to poverty). There is evidence that many mountain regions have become more disaster-prone (Kohler and Maselli, 2009). Climate change is an important contributing factor, because it increases the risk of extreme events and reduces the resilience of both ecosystems and people (Kohler, Wehrli and Jurek, 2014). Migration, urbanisation and other factors also play a role, as more and more people move into areas exposed to natural hazards.

Apart from the direct cost to human lives and property, disasters have significant waste implications. Disasters can generate a huge amount of waste in a very short time, overwhelming the capacities of municipalities and waste management facilities. Disaster waste can affect human health by contaminating drinking water and through exposure to hazardous waste, cripple local infrastructure, and hinder rescue and rehabilitation efforts (for example, debris blocking access routes and roads). The waste is often mixed with vegetation and other debris, which further complicates separation and collection.

It is difficult to assess the total waste generated by disasters but research from various disasters in the US and the 2004 Tsunami in the Indian Ocean indicate that the waste generated in each community was equivalent to between 5 and 15 times their normal annual waste generation (Reinhart and McCreanor,1999; Basnayake, Chiemchaisri and Visvanathan, 2006). The 2015 earthquake in Nepal, which killed more than 9,000 people and destroyed 800,000 buildings, generated 3.94 million tons of debris in Kathmandu valley only. This was equivalent to 11 years of waste (Gyawali, 2015).



Damaged bridge from flooding, Pakistan. *Photo © Wikimedia/Horace Murray*

The composition of disaster waste varies both with the type of disaster and the natural and built environment affected. The largest proportion of disaster waste is generally construction and demolition waste, comprised of concrete, steel, wood and other building materials, which can also include asbestos insulation and other hazardous waste. The 2008 earthquake near Chengdu in Sichuan, China, for example generated about 20 million tons of building waste (Boston.com, 2008).

Disaster waste is not only generated by the disaster itself but also during the response and recovery phase (Modak, Wilson and Velis, 2015h). Emergency and rebuilding operations generate substantial amounts of waste because of the lack of segregation, and uncontrolled storage and dumping. This waste might, for example, consist of health care products, packaging from basic provisions or demolition waste. Proper management of disaster waste can provide resources to support the recovery effort rather than causing long-term damage. For example, recycling rubble and steel debris into new building materials can reduce the costs of rebuilding affected communities.

Disaster risks in mountain cities

As a result of population growth, rural to urban migration and an increasing shortage of space, cities in developing countries are sprawling outwards, often into hazard-prone areas such as alongside riverbanks or steep hillsides, which were previously devoid of development (Schuster and Highland, 2007; Jeschonnek et al., 2014). The growth of these cities often exceeds the capacity of authorities to develop and maintain adequate infrastructure, resulting in the development of informal settlements and slum areas which are highly vulnerability to natural hazards (Jeschonnek et al., 2014). Globally, about 56 per cent of all cities are exposed to at least one type of natural hazard – cyclones, floods, droughts, earthquakes, landslides or volcano eruptions (Gu et al., 2015).

In mountainous regions, people (particularly young men) from small mountain communities, move to large cities in search of better prospects. Due to limited financial resources, they often move to the growing slum areas and informal settlements, which lack even the most basic infrastructure. These tend to be located on steep hillsides around mountain cities and can be particularly vulnerable to landslides triggered by heavy rain and the removal of vegetation. The risks in these areas are often exacerbated by the poor quality of homes and infrastructure which are vulnerable to collapse, and because these areas lack early warning systems and evacuation plans (Jeschonnek et al., 2014).

Mitigating urban risk is an urgent priority for national governments as well as urban municipalities, given the continued urbanization projected for the coming decades, particularly in Asia and Africa. This includes obtaining good quality data on shocks, stresses, hazards and vulnerabilities; implementing more stringent construction standards and plans for safer buildings and infrastructure; legalizing and regularizing informal settlements; preserving productive and protective ecosystems (for example through an ecosystem-based adaptation approach); and building local capacity to respond rapidly to disasters.[11]

Disaster waste – managing the equivalent of 11 years of waste after the 2015 Nepal earthquake

Nepal was struck by a 7.8 magnitude earthquake on the 25th of April 2015 followed by another powerful quake and numerous aftershocks, killing 9,000 people and injuring 100,000; it destroyed 500,000 houses and damaged 269,000 more (UNOCHA, 2015). In the Kathmandu valley, approximately 3.94 million tons of debris was generated – in other words the "equivalent of nearly 11 years of waste was generated in one day" (Gyawali, 2015).

The waste generated included building, medical, electrical, laboratory, industrial and petroleum waste and paint materials, some of which ended up in groundwater or rivers (Ministry of Science, Technology and Environment, 2015), as well as health care related waste used in the response phase. The largest amount of waste was building debris, consisting of bricks, wood and concrete (Ministry of Science, Technology and Environment, 2015).

The enormous amount of waste and debris overwhelmed the waste management capacities of the Nepali Government and its citizens; in fact, the municipalities responsible for waste management were already having difficulties managing waste prior to the earthquake. Only 5 out of 191 municipalities had sanitary landfill sites and the Solid Waste Management Act of Nepal did not cover disaster waste. Therefore, the earthquake put an enormous burden on municipalities that were already struggling (Ministry of Science, Technology and Environment, 2015); municipalities were not able to manage the waste for several weeks after the earthquake (UNEP, 2015).

Clearing the waste was largely the responsibility of local communities. People tried to clear their own debris and reuse bricks, wood and other materials to reconstruct their homes. This significantly reduced the volume of waste that had to be disposed of, but also created safety concerns as most people did not have the tools or knowledge needed to safely rebuild their houses. It is estimated that 80 per cent of the debris in Kathmandu will be recycled with or without the Government's help (Gyawali, 2015).

Building contractors contributed by buying reusable bricks and wood to keep up with the increased demand. The United Nations Development Programme also supported in managing debris and demolition activities by training demolition workers and local community members under a cash-for-work scheme. As of November 2015, this scheme had managed to safely demolish 2,500 buildings, assess 4,000 buildings, manage 138,000 cubic metres of debris and hire almost 2,800 people (UNDP, 2015a).

Earthquake damage in Bhaktapur. *Photo © UNDP Nepal/Laxmi Prasad Ngakhusi*


Earthquake damage in Sankhu, a particularly badly affected town in northwestern Nepal. Photo © UNDP Nepal/Laxmi Prasad Ngakhusi


Earthquake damage in Sankhu. Photo © UNDP Nepal/Laxmi Prasad Ngakhusi

Plastic Pollution and Downstream Impacts

One of the far-reaching implications of waste in mountains, particularly waste that is unmanaged or poorly managed, is that it might not always stay in the mountains. Solid waste can end up in rivers, lakes or wetlands after it enters sewage systems, is washed down by rainwater, or blown away by wind. Lakes, including artificial lakes and reservoirs, can act as temporary storage facilities for all kinds of litter, but it is rivers that are the key pathways to lowlands and coastal areas – for water, sediments, pollutants and litter. Once rivers have discharged their content into the ocean, it becomes 'marine litter'. Waste that was once disposed of on a mountain can find itself on the floor of submarine canyons (Tubau et al., 2015).

In recent years, there has been an increase in interest in marine plastics. However, few studies have focused on plastic accumulation in freshwater systems and rivers, despite their important role in transporting plastics to the sea (Williams and Simmons, 1997; Galgani et al., 2000; Acha et al., 2003; Rech et al., 2014).

Plastics production reached 300 million tons in 2014 (Plastics Europe, 2015). Plastic has many applications and advantages and is used in almost all economic sectors because of its specific characteristics – its low cost, durability, strength and lightness. Unfortunately, it is precisely these characteristics that make plastics so persistent and widespread in the environment, causing huge challenges in terms of impact and management (UNEP and GRID-Arendal, 2016).

Plastic litter is generally subdivided into larger macroplastics and smaller microplastics, which measure less than 5mm (GESAMP, 2015). Microplastics are either purposefully manufactured (for example, microbeads in abrasives or in cosmetics) or are the result of erosion and fragmentation of larger plastic items. The degradation of plastics depends on physical, chemical and biological conditions but is enhanced by exposure to ultraviolet light and air. Fragmentation into smaller particles increases the dispersal of plastics into the environment.

Environmental concerns over plastic are not only related to the volume or aesthetics of waste, but mainly to the impact they might have on humans and other living organisms. Both terrestrial and marine organisms can experience mechanical problems, resulting from ingestion and entanglement. Even when plastic disintegrates into smaller pieces, the polymer within may not completely break down into its natural chemical elements. Most plastics also contain additives to improve their properties such as flame retardants and plasticizers (for example, phthalates), which can easily leach out to contaminate the surrounding environment. Some of these substances are known to be toxic and cause endocrine disruptions and other potential risks to living organisms (Oehlmann et al. 2009; Teuten et al., 2009) including humans (Talsness et al., 2009).

Plastic pollution can also clog drainage systems, which are very important for channelling excess water and preventing flooding, especially after heavy rainfall. When water pipes are blocked by plastic debris, the diverted water can cause local flooding, which, in turn, has the potential to transport more plastics.

Plastic pollution is directly linked to human activity, population density and the quality of waste management (Jambeck et al., 2015). Without proper waste management, even low-density populations can heavily pollute freshwater systems with plastics. While there are major uncertainties about the actual quantities of plastic debris in lakes and rivers, high concentrations of microplastics have been found even in remote water bodies. Examples include Lake Hovsgol, a remote lake in a mountainous, sparsely-populated region of Mongolia (Free et al., 2014); in fish from Lake Victoria (Biginagwa et al., 2016); in sediments of remote lakes in the Tibetan Plateau (Zhang et al., 2016); in lake sediments in Italy (Fischer et al., 2016); in the Laurentian Great Lakes (Driedger et al., 2015); in the Yangtze (Zhao et al., 2014); and in the Danube (Lechner et al., 2014).

The lack of available data does not allow for a comprehensive assessment of the long-term impacts of plastics on mountain ecosystems and human health. Further research is needed, but prevention, mitigation and adaptation strategies and policies should be urgently designed to address identified sources and pathways to prevent further plastic contamination – including the dispersal of persistent organic pollutants in freshwater systems on which human populations depend for drinking water and food resources.

Plastics Ban in Rwanda

Rwanda, a mountainous country in East Africa and often referred to as the country of a thousand hills, set an example to the rest of the world in reducing plastic pollution when the Government decided to ban non-biodegradable polythene bags (FAOLEX, 2008). The manufacture, sale, import and use of plastic bags is forbidden and visitors' luggage is examined on arrival in Rwanda, to prevent plastic bags being brought into the country.

The main driver behind the ban was the fact that Rwanda lacked the means to sustainably manage plastic waste, triggering serious health and environmental risks. The bags littered the surroundings, clogged drainage systems causing floods during the rainy season, and released toxic fumes when people burnt their waste.

The law was part of the 'Vision 2020' plan to transform the country into a sustainable, knowledge-based, middle-income nation by the year 2020 (Government of Rwanda, 2013). In addition to enacting the law, the Government has invested in awareness campaigns on television and in schools to instil an environmental consciousness among its citizens (Van der Poel, 2013). The measures seem to have worked: while the rest of the world is struggling to reduce plastic production and pollution, Rwanda has been praised for its environmental protection measures and the capital, Kigali, has a reputation of being the cleanest city in Africa, which contributed to the city receiving the UN Habitat Scroll of Honour Award in 2008.

The ban has also boosted the economy. Companies that used to produce plastic receive tax incentives to recycle it instead and a new community-based market was created for environmentally-friendly bags made from local materials. The country has also seen a large increase in tourism, which has been partly attributed to Rwanda's clean reputation.

The fact that Rwanda has managed to eliminate all plastic bags is an extraordinary achievement in itself. However, not everybody is happy with the ban; many vendors think that paper bags are not a good alternative because they tear and are not suitable for all types of content. There is also a concern now about the increasing amount of paper bags and no real research has been done into the costs and benefits of such a ban. As with many other prohibited goods, there is now a profitable black market in plastic bags (Dundas et al., 2013).

Kigali, Rwanda. *Photo © iStock/Sloot*

Waste Crime

Waste crime involves the illegal handling of waste, which can lead to environmental, social and economic challenges for countries – ranging from a simple nuisance, through to serious environmental contamination and threats to public health. At the global level, there is very little information on the extent of waste crime in mountainous regions. However, the remoteness of many mountain regions is likely to make them easy targets for criminals, much like dumping on the high seas. The illegal or informal dumping of solid waste in mountain regions involves all types of waste including household, industrial and construction waste. Industrial activities such as mining in mountain areas, are of particular concern, especially where operations fail to apply environmental regulations for the management of waste. In many cases, these operations generate hazardous waste, which carry risks for the environment and human health.

Reasons for waste crime

Illegal or illicit waste management can occur due to the high costs of waste management (particularly hazardous waste), weak governance, loopholes in regulations or a lack of awareness. It presents significant opportunities for illegal actors to operate in a market with relatively few risks – as there are limited controls or weak enforcement mechanisms. Waste crimes can happen within a country or involve trade between countries. While illegal or informal household waste dumping practices are widespread, countries with weak governments and poor enforcement mechanisms are more vulnerable to unsound waste management practices.

Illegal dumping

Cases of illegal or informal dumping, driven by tax avoidance or weak governance (including the failure to apply environmental regulations) occur within countries. Financial mechanisms such as landfill taxes or waste management fees exist to provide sound and reliable waste management services. However, unscrupulous actors seek to avoid these fees by illegally dumping waste elsewhere. Companies who provide waste disposal services may also generate 'easy' revenue by dumping waste illegally, rather than paying fees to dispose of waste in formal landfills. Dumping is committed by both individuals and companies. Illegal dumping can be part of a broader chain of legal waste management activities, making it difficult to identify and distinguish those involved (Rucesvka et al., 2015).

Examples exist across different countries. The illegal dumping of toxic and industrial waste was reported in the Ibaraki mountains northeast of Tokyo, Japan in 2014. The waste included debris from the earthquake and tsunami in 2011 and toxins such as lead and chromium. The toxins, in particular, affected the area's soil and water bodies (The Japan Times, 2014).

In 2015, illegal dumping of household and industrial waste was reported in the Blue Mountains in Australia. The clean-up activity organized by the authorities recovered 8 tons of waste including large amounts of dumped asbestos (Blue Mountains City Council, 2015).

Unauthorized dumping of industrial and construction waste was reported in the Northern Caucasus; construction companies used rudimentary waste disposal methods in preparation for the 2014 Sochi Winter Olympics in Russia (Sobol, 2015). As a result, dozens of illegal landfills were reported throughout the Krasnodar Region where Olympic construction companies covertly disposed of their waste (Digges, 2013). The role of law enforcement agencies and federal authorities are crucial in sound waste management practices; weak surveillance often leads to illegal activities (Sobol, 2015).

Several European countries have been in breach of European Union landfill legislation, posing serious risks to ecosystems and human health. The Campania region in southwest Italy has been referred by the European Commission to the European Court of Justice for its long-running failure to manage waste adequately (European Commission, 2014). Illegal landfills are also associated with other illegal activities such as landfill fires. Campania, has been nick-named the 'Land of Fires' because, since the 1980s, organized criminal groups have been burning and burying toxic waste (D'Alisa et al., 2015).

Due to disparities in economic development or differences in costs between regions, there is a tendency for waste to be traded between industrial and developing countries, including illegal shipments. At the global level, however, there is very little information on the extent to which mountain regions are the targets of such activity.

A waste dump close to Kravchenko, a village 18km north of Sochi, was due to be closed several years prior to the games. Due to the construction boom that occured as Sochi prepared to host the Olympics, locals say the waste dump grew vertiginously. Photo © Abbas Attilay/Radio Free Europe/Radio Liberty

Disasters can reveal shortcomings

At times, disasters or accidents can trigger investigations and lead to the discovery of the illegal trade in waste, informal dumping or obsolete storage sites. In 2013, an extreme weather event triggered the flooding of the Tskhenistskali River in northern Georgia, close to the village of Tsana. The flood washed away the wall of a waste burial site containing over 50,000 tons of arsenic waste material – a by-product of the smelting of metal ores. The arsenic waste material was stored on the site of an old mining factory that had ceased operation in the early 1990s (UNEP, OSCE, UNDP, 2016). Often, developing countries or countries in transition lack the financial resources to map out and/or remediate hazardous waste sites, posing serious risks to the environment and human health.

The Extractives industry (Oil, gas, minerals)

The extractive industry (oil, gas, metals and minerals) produces large amounts of waste, some of it hazardous. In these circumstances sound and safe waste management is particularly important. Criminal behaviour may involve breaching environmental and safety regulations for existing activities, or neglecting risks from previous operations. In addition, loopholes in legislation and weak enforcement mechanisms provide the means for illegal or illicit activities.

In the European Union, mineral waste is one of the largest waste streams, generating 63 per cent of total waste in the 28 EU countries in 2012 (Eurostat, 2015). A number of EU countries have been taken to court for failure to comply with EU legislation on mining waste. Romania, one of the countries that makes up the Carpathian mountain range, is struggling to deal with abandoned tailing ponds, including the Bosneag tailing pond. The European Commission took Romania to court for failure to comply with European legislation on mining waste (European Commission, 2014).

Armenia, a mountain country in the South Caucasus, has been carrying out mining activities for decades. However, these activities are also associated with persistent environmental transboundary concerns and risks. The failure to enforce environmental legislation continues to allow unscrupulous actors to manipulate the reporting of mining waste quantities and qualities, and disregard safety and security issues – creating the potential for interstate tensions (Stefes and Weingartner, 2015).

Recommendations: The Waste Solutions

New knowledge for informed decision-making and implementation of solutions

Implement waste monitoring programmes. Monitoring schemes are needed to establish a baseline against which actions can be measured, and to assist in developing a systematic overview of the problems and their causes. In popular mountain tourist areas, data on visitor numbers, length of stay and activities, combined with the experience and observations of local communities, are important for managing and anticipating waste removal and disposal requirements. Risk assessments of waste management in mountain areas are also needed. This includes the potential risk for downstream areas from both large and small-scale dumping (whether legal or illegal) and industrial waste.

Fund scientific research. Research is needed to better understand the relationship between different waste streams and their biophysical impacts on sensitive mountain environments, on the health of mountain communities, and on the linkages between upstream and downstream areas. An international research agenda on mountain waste issues should be considered, taking an integrated approach involving both mountain and downstream scientific networks. The waste implications of sectors such as forestry and agriculture, which have not been addressed in this report, should also be included in future research initiatives.

Applied and participatory research is needed to better understand existing public attitudes to waste and how to best incite behavioural change and adoption of sound waste management practices in challenging environments and socio-economic conditions.

Capacity building and awareness raising

Build awareness at all levels of the large potential downstream impacts and global nature of certain waste streams in mountain environments, and the threats posed to human health. The focus should be on people living in mountain communities and those who visit mountains on a temporary basis, such as tourists. This should start with promoting sustainable consumption through the 3Rs: reduce, reuse and recycle. Awareness raising should also talk about risks to public health of inappropriate disposal and treatment of waste and appropriate and economic alternatives. Open burning of non-biodegradable waste should be strongly discouraged or even banned. A preventative approach is needed to make sure that sustainable waste management practices are introduced before waste problems become too severe.

Prevent waste disposal in mountain areas wherever possible. A combination of both education and awareness raising to promote waste-reduction or waste-eliminating behaviour, and smart policies and instruments, are needed. This is particularly needed in mountain areas, as the costs of waste collection and removal are increased by remoteness, rugged terrain and poor infrastructure.

Build the capacity of mountain communities, and both small and large municipalities to plan for sound management of waste. Integrated management plans and approaches to waste management are needed that include avoidance/prevention (including with regards to illegal dumping), recycling, minimisation, treatment and disposal. Promoting local capacity and use of local knowledge is important to ensure measures are appropriate for local conditions.

Develop small-scale solutions that are adapted to more remote mountain settings. Options include promoting community-based, alternative options to landfills for organic wastes and waste collection centres to promote the collection and sorting of non-organic recyclables. Communities should consider working together to create shared collection centres in order to accumulate a greater volume of recyclables that can then be sold. New landfills should be sited in areas that minimise the potential for runoff that can contaminate important water sources. Existing landfills that pose risks should be relocated where possible for the same reasons. Following the waste hierarchy where waste cannot be reused or recycled due to technical, economic or environmental limitations, systems that convert municipal waste to energy (WtE) should also be explored particularly in more populated areas, as alternatives to or as means of reducing waste to landfilling. This can also lead to reduced greenhouse gas (GHG) and short lived climate pollutants (SLCPs) emissions, therefore contributing to climate change mitigation opportunities. Technological innovation research should be also be supported to explore new methods applicable to mountain settings, e.g. for waste to energy, and composting.

Ensure that the tourism industry – and tourists – are educated on waste issues, and contribute to the financing and management of waste solutions in mountains. In line with the polluter pays principle, the mountain tourism industry and tourists themselves should bear responsibility for financing the management of the waste created in the areas they visit. Waste management practices should be integrated in the tourism industry, such as bring-back-your-waste policies and re-directing fees (e.g. entry fees, camping fees) into waste management operations. Dialogue and partnerships between tourism operators and local communities should be encouraged. Tools such as sustainable tourism eco-labels and guidelines should be considered for the mountain context, to drive innovation and best practices on reducing waste and greening the tourism sector in mountains.

Promote education on waste management within the mountaineering community. The mountaineering community's global governing bodies, such as the International Climbing and Mountaineering Federation (UIAA) and the International Federation of Mountain Guide Associations (IFMGA), as well as national mountaineering organizations should revise current procedures, guidelines, training and certification practices to integrate and instil environmental values, including sensitization of the consequences of waste and its management. The mountaineering community should also actively engage in the broader policy and management discussions to bring the voices and experiences of mountaineers to the decision-making table.

Strengthen policies, enforcement capacities and monitoring for high-risk sectors in mountains

Promote national and global dialogues across sectors such as environment, tourism, industry, and defence, involving government, the private sector and civil society to promote understanding of challenges, risks and opportunities for waste management in mountain regions, and to reduce potential conflict across national borders. Information exchange and knowledge platforms should also be considered to share best practices.

Strengthen national legislation, enforcement capability and monitoring of the mining sector and the management of mining waste. This includes strengthening environmental standards and targets, and ensuring that the responsible law enforcement authorities have the required skills and resources to perform their duties so that mining projects proceed in accordance with the law. Ensuring transparency and access to information is necessary for monitoring and creating incentives for all stakeholders to play by the rules, and should be part of the mining licensing permit condition. Remediation plans should also form part of any license, and a security fund should be established at each mine site large enough to cover the estimated environmental liabilities upon closure and remediation.

Ensure private sector responsibility. Private contractors and companies, whether it be in tourism, mining, construction or other sectors, should be made responsible for managing the wastes generated through their activities. Enforcement should be ensured through legal contracts. Corporate social responsibility should also be encouraged.

Strengthen and protect civil society organisations' ability to monitor compliance in mining and other sectors. Civil society has a strong role to play in ensuring that mining companies "play by the rules" and follow adequate standards for environmental stewardship. These organisations also have an important role in fighting corruption and illegal activity, and monitoring of public procurement and service delivery (e.g. municipal waste services).

Increase the capacity of artisanal and small-scale miners to reduce their environmental and health effects. Alternative technique to the use of mercury and cyanide exist, such as gravity methods. The awareness and capacities of artisanal miners should be increased to apply such methods.

Prepare disaster waste management plans for areas with a high exposure to natural disasters. Mountain areas are particularly vulnerable to earthquakes, landslides and floods which can cause immense amounts of waste. Immediate waste management is needed to facilitate rescue efforts and also to reduce the spread of disease and environmental impact. Disaster waste management plans should be prepared before they are needed to facilitate effective use of scarce resources both during and after extreme events.

Notes

1. Short-lived climate pollutants remain in the atmosphere for a much shorter period of time than longer-lived climate pollutants, such as carbon dioxide (CO_2). Their relative potency, when measured in terms of how they heat the atmosphere, can be tens, hundreds, or even thousands of times greater than that of CO_2. The impacts of short-lived climate pollutants are especially strong over the short term. Reducing these emissions can make an immediate beneficial impact on climate change.
2. For the purposes of our analysis large mountain cities are those with more than 1 million inhabitants, located above 1,500 metres ASL. Exceptions include some mountain cities that have populations just under 1 million inhabitants (for example, Arequipa, Peru, and Naucalpan, Mexico), as well as other cities just below 1,500 metres ASL but which nevertheless are considered mountainous (for example, Ulaanbaatar, Mongolia and Kathmandu, Nepal). Please note this analysis may not be fully comprehensive or accurate due to a lack of reliable data. National statistics were used to compile this list.
3. Hazardous household waste includes paints, pesticides, pharmaceuticals, certain detergents, personal care products, fluorescent tubes, oil, batteries, print cartridges and e-waste.
4. To download the guidance manual: https://wedocs.unep.org/rest/bitstreams/17340/retrieve
5. The informal sector, also known as the informal economy, is the non-regulated, non-tax paying part of the economy.
6. The hierarchy of solid waste is understood as the prioritization of preventative actions: waste reduction, resource recovery, treatment, reuse or recycling; with safe disposal of waste being the final option.
7. Waste Management Law N° 755 was approved in October 2015 (The Plurinational State of Bolivia, 2015)
8. According to a report by the National Programme of Solid Waste Management (PNGIDS), in Ecuador there are 144 dump sites and 77 landfills. The aim of the PNGIDS it that by 2017, 70 per cent of the population will dispose of its waste in sanitary landfills instead of dumping sites (Ministry of Environment, Ecuador; n.d.)
9. EPR instruments can include: product take-back requirements; economic and market-based instruments; regulations and performance standards; and accompanying information-based instruments.
10. See http://www.centralasia-travel.com/en/actions/clean-snow#action_award_a for more information.
11. The Medellin Collaboration for Urban Resilience supports 4,000 cities globally and is committed to helping cities achieve Target 11.b3 of the SDGs – to develop holistic disaster risk management at all levels for cities and human settlements by 2020. For more information, visit https://www.cityresilience.org/mcur

Acronyms

3Rs	Reuse-Reduce-Recycle
ABIS	Asociación Boliviana de Ingeniería Sanitaria
AIT	Asian Institute of Technology
ASL	Above sea level
BBIA	Bio-based and Biodegradable Industries Association
BMLFUW	Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management
CBD	Convention on Biodiversity
CDM	Clean Development Mechanism
CERs	Certified Emission Reductions
CLTS	Community Led Total Sanitation
CMC	Clean Mountain Can
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
ETHZ	Swiss Federal Institute of Technology in Zurich
EU	European Union
FoE	Friends of the Earth
FAO	Food and Agriculture Organization of the United Nations
FYROM	Former Yugoslav Republic of Macedonia
GHG	Greenhouse gas
GIZ	German Corporation for International Cooperation
GWMO	Global Waste Management Outlook
HASP	High Altitude Sustainability Pakistan
ICIMOD	International Centre for Integrated Mountain Development
ICJ	International Court of Justice
IETC	International Environment Technology Centre
IFMGA	International Federation of Mountain Guides Associations
ILO	International Labour Organization
INDCs	Intended Nationally Determined Contributions
ISWA	International Solid Waste Association
MSW	Municipal solid waste
NAMA	Nationally Appropriate Mitigation Action
NGO	Non-Governmental Organization
OECD	Organisation for Economic Co-operation and Development
PM	Particulate matter
SLCPs	Short Lived Climate Pollutants
SWM	Solid waste management
TB	Technisches Büro
UIAA	International Climbing and Mountaineering Federation
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNSCR	United Nations Security Council Resolution
WCMC	World Conservation Monitoring Centre
WtE	Waste to energy

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Mountains play an essential role in supplying water, energy, food and other services to millions of people living in the mountains and downstream. Ensuring the continued supply of these services has never been more important. However, many mountain regions are experiencing a growing solid waste problem, from ever-expanding urban sprawls and cities, increasing consumption patterns, existing and past mining operations, tourism activities and practices of illegal dumping. The good news is that there are many options available to prevent and manage waste in mountain environments, in ways that protect mountain ecosystems and people, and prevent problems from migrating downstream. This report highlights both the challenges and the solutions for sound waste management in mountain regions.