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- Source separating solutions for mountain refuges
- 'Gloggnitzer Huette' sanitation system
- Solid waste management in mountain refuges

Solutions for mountain regions

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Editors / ***Redaktion***

Elke Müllegger, Günter Langergraber, Markus Lechner • EcoSan Club

Journal Manager / ***Journal Management***

Fritz Kleemann

Contact / ***Kontakt***

ssp@ecosan.at

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Sustainable Sanitation Practice (SSP) aims to make available high quality information on practical experiences with sustainable sanitation systems. For SSP a sanitation system is sustainable when it is not only economically viable, socially acceptable and technically and institutionally appropriate, but it should also protect the environment and the natural resources. SSP is therefore fully in line with SuSanA, the Sustainable Sanitation Alliance (www.susana.org). • SSP targets people that are interested in sustainable sanitation systems and the practical approach to it. • Articles are published after blind review only. • Sustainable Sanitation Practice is published quarterly. It is available for free on www.ecosan.at/ssp.

Sustainable Sanitation Practice (SSP) hat zum Ziel praxisrelevante Information in hoher Qualität im Zusammenhang mit „sustainable sanitation“ bereit zu stellen. „sustainable“ also nachhaltig ist ein Sanitärsystem für SSP wenn es wirtschaftlich machbar, soziokulturell akzeptiert, technisch als auch institutionell angemessen ist und die Umwelt und deren Ressourcen schützt. Diese Ansicht harmoniert mit SuSanA, the Sustainable Sanitation Alliance (www.susana.org). • SSP richtet sich an Personen, die sich für die praktische Umsetzung von „sustainable sanitation“ interessieren. • Artikel werden nur nach einer Begutachtung veröffentlicht. • Sustainable Sanitation Practice erschient vierteljährlich, kostenlos unter: www.ecosan.at/ssp.

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Publisher: EcoSan Club, Schopenhauerstr. 15/8, A-1180 Vienna, Austria • chairperson: Günter Langergraber • website: http://www.ecosan.at/ • scope: EcoSan Club was funded as a non profit association in 2002 by a group of people active in research and development as well as planning and consultancy in the field of sanitation. The underlying aim is the realisation of ecological concepts to close material cycles in settlements.

Medieninhaber: EcoSan Club, Schopenhauerstr. 15/8, A-1180 Vienna, Austria • Obmann: Günter Langergraber • Gegenstand des Vereins: Der EcoSan Club wurde 2002 als gemeinnütziger Verein von einer Gruppe von Personen gegründet, die in Forschung, Entwicklung, Planung und Beratung in der Siedlungshygiene - Sammlung, Behandlung oder Beseitigung flüssiger und fester Abfälle aus Siedlungen - tätig waren und sind. Das Ziel des EcoSan Clubs ist die Umsetzung kreislauforientierter Siedlungshygienekonzepte (EcoSan Konzepte) zu fördern, um einen Beitrag zum Schutz der Umwelt zu leisten.

Editorial

There are thousands of public and private mountain refuges located in the alpine regions. The increased number of visitors has raised the concerns on the environmental impact on the sensitive ecosystems.

To ensure sustainability, integrated management of the alpine infrastructure is needed. Water supply, energy, wastewater treatment and solid waste management need to be assessed together for planning the infrastructure in refuges. A main criterion for ensuring reliable and efficient operation of the refuge's infrastructure is the training and involvement as well as the engagement of the operator.

Issue 8 of Sustainable Sanitation Practice (SSP) on „Solutions in mountain regions" shows some examples of solutions for mountain regions.

- The first paper gives a short overview on 3 examples showing source separating sanitation solutions for refuges. Unfortunately we were not able to get full papers from these examples. Nevertheless we think that these interesting examples should be included.
- The second paper describes the sanitation system for the 'Gloggnitzer Huette', a small mountain refuge located in a sensitive drinking water catchment.
- The third and final contribution summarises the findings of a project on integral evaluation of supply and disposal systems in mountain refuges in relation to solid waste management.

The thematic topic of SSP's next issue will be „Biogas systems" (issue 9, October 2011). Information on further issues planned is available from the journal homepage (www.ecosan.at/ssp). As always we would like to encourage readers and potential contributors for further issues to suggest possible contributions and topics of high interest to the SSP editorial office (ssp@ecosan.at). Also, we would like to invite you to contact the editorial office if you volunteer to act as a reviewer for the journal.

SSP is available online from the journal homepage at the EcoSan Club website (www.ecosan.at/SSP) for free. We also invite you to visit SSP on facebook (www.facebook.com/SustainableSanitationPractice).

With best regards,
Günter Langergraber, Markus Lechner, Elke Müllegger
EcoSan Club Austria (www.ecosan.at/ssp)

Content

Examples of source separating sanitation solutions for mountain refuges

This paper shows three examples of source seperating sanitation systems in different regions of the Alps

Authors: Günter Langergraber, Elke Müllegger

Abstract

The paper presents 3 examples for source separating sanitation systems installed in the Alps. The examples described are 1) the Bettelwurf Hütte in Austria, 2) the Refugio Casera Bosconero in Italy, and 3) the Britannia Hütte in Switzerland. In these examples a main driver for installing source separating systems has been to reduce transport costs and not reuse.

Introduction

In this paper we introduce 3 examples of solutions for mountain refuges that are based on source separation and treatment of separated waste streams. Separation of wastewater streams (e.g. dry toilets) lowers the pressure on water supply and reduces the environmental impact of a refuge (Weissenbacher et al., 2008). The aim of the paper is not to give a full description of the examples but to provide the interested reader with basic information. As it can be seen from the examples reuse is not the reason to implement source separating systems. However, the reduction of transport costs was the main driver for all refuges.

The examples presented inn this paper are:

- Bettelwurf Hütte, Austria,
- Refugio Casera Bosconero, Italy, and
- Britannia Hütte, Switzerland.

Bettelwurf Hütte, Austria (www.bettelwurfhuette.at)

The Bettelwurf Hütte is located at 2077 m altitude in the natural protection area „Karwendel“ in Tyrol, Austria. Below the refuge is the water protection area of a nearby community (Figure 1 and Figure 2). The refuge is accessible by a 2.5 hours walk only and is open from mid-June to mid-October. Materials can be transported to and from the refuge with a cable car. There are 3 staffs and around 3‘000 daily visitors per year. The Bettelwurf Hütte has 66 beds and around 2000 overnight stays per year. Due to its location above the water protection area waste from the Bettelwurf Hütte has to be transported into the valley.

Figure 1: Location of the Bettelwurf Hütte (Picture: Amor, 2006)

Key Messages:

- Source separating sanitation systems can be implemented at mountain refuges
- Source separating systems can reduce transport costs
- Operation and maintenance of the system as well as the engagement of the operator of the refuge are key for success

Figure 2: The Bettelwurf Hütte (Picture: Amor, 2006)

Figure 3: Bettelwurf Hütte with new sanitation facility and chambers for faecal matter (lower right corner) (Picture: Amor, 2006).

Figure 4: UDDTs (left, without separation walls) and urinals (right) during installation (Picture: Amor, 2006).

To reduce the amount of wastewater produced a urine-diverting dry toilet (UDDT) was tested in the season 2002. Although the boundary conditions for the test UDDT were quite harsh, e.g. only one toilet for all daily visitors, no separate toilets for men and women, no urinal for men and up to 150 users per day, the results were promising (Kaschka, 2005).

The results from the test UDDT have been used to optimize the design of the sanitation facility (Amor, 2006). In total 6 UDDTs and 4 urinals have been installed in the new sanitation facility. Faecal matter is collected in 60 L barrels and transported in the valley with the cable car. Wastewater from the kitchen is treated with a fat removal and soaked away.

Already in the first year of operation high acceptance of the system could be achieved. It has to be noted that the person running the refuge has huge impact on the overall performance of the system.

Refugio Casera Bosconero, Italy

An integrated system, called Energianova, has been developed for the Refugio Casera Bosconero (Forno di Zoldo, Belluno, Italy). The refuge is situated in the Dolomiti mountains at an altitude of 1457 m. The Refugio Casera Bosconero (Figure 5) is open during the summer month only and popular among climbers. Material for the refuge including gas for the kitchen has to be transported by helicopter.

The integrated system (Figure 6) consists of the following: Wastewater is separated into greywater, urine and faecal matter. A squatting type separation toilet was installed for daily visitors (Figure 7) whereas sitting type toilets were installed for overnight guests. Furthermore kitchen wastes are shredded in a kitchen mill. The four fractions are treated using different concepts. In particular a subsurface horizontal flow vegetated bed planted with local

Figure 5: Refugio Casera Bosconero (Picture: G. Langergraber).

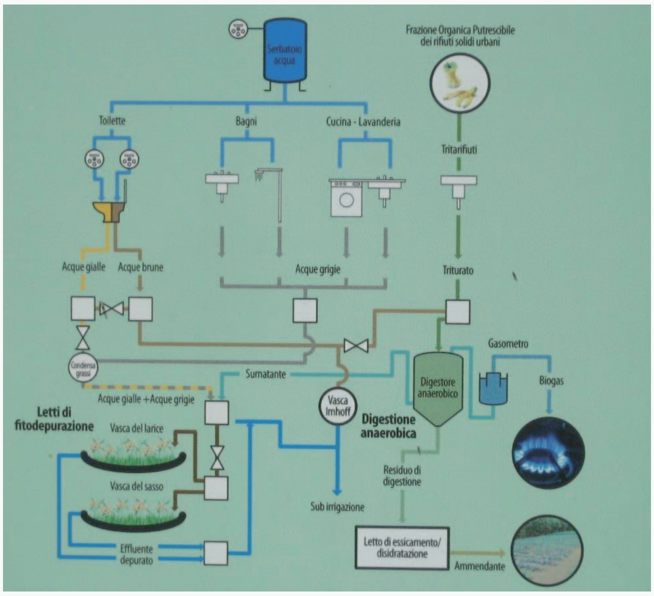

Figure 6: The integrated system (Picture: G. Langergraber).

Figure 7: Squatting type separation toilet for daily visitors (Picture: G. Langergraber).

Figure 8: The constructed wetland system (Picture: G. Langergraber).

Figure 9: The biogas plant (Picture: G. Langergraber).

vegetation (Figure 8) is installed for treating grey and yellow water. Anaerobic digestion (Figure 9) is used for treating brown water with the addition of kitchen waste, with the aim to recover energy directly available for the kitchen (Cossu et al., 2007). By producing biogas a main aim was to reduce the number of helicopter flights for transporting gas for cooking. The design of the system was carried out within a research project by the University of Padova from 2004-2006. The horizontal flow constructed wetland was built in 2006 and its performance was monitored in 2006 and 2007. The showing abatement of COD and total N were around 50 %, total P around 40 % and MBAS around 60 %. Among the local plants species, Mentha (mint) was the most effective in colonising the bed. The anaerobic digestion was implemented in 2007.

Britannia Hütte, Switzerland (http://www.britannia.ch)

The Britannia Hütte is located in the „Walliser Alpen" in the Swiss canton Valais at an altitude of 3030 m. The refuge is operated during the summer months only but also provides sleeping facilities during the winter season. Within the EU funded FP7-project SANBOX a novel sanitation approach for remote tourist facilities in Europe was developed. The SANBOX system aims to reach high treatment performance, recycle water and nutrients and use solar power as energy source. The vision is to come close to a self-sustaining zero effluent treatment system. The SANBOX system is currently tested at 3 different locations: 1) Secovlje Salina Nature Park, Piran, Slowenia, 2) Britannia Hütte, Saas Fee, Switzerland, and 3) Kaja Student Dormitories, Ås, Norway (SANBOX, 2011).

At the Britannia Hütte the waste from the UDDTs is collected in bins and flown by helicopter to the valley below. SANBOX tests a solution that provides more comfort to the guests and reduces helicopter transport, local emissions and thus, the environmental foot print of the waste handling system. According to SANBOX (2011) the prototype of the system at the Britannia Hütte has the following components (Figure 10):

- Dry latrines are replaced with vacuum toilets. This technology has been proven under challenging conditions on cruise ships, buses and trains. The installed vacuum toilets need only 0.8 L water per flush and can therefore be supplied with water from kitchen and washing facilities that has been treated in a biofilter.
- Wastewater from the toilets is treated in a box, attached to the south face of the lodge. The design of the box is based on greenhouse technology. The greenhouse enables the utilization of the strong solar radiation available at this high altitude and will provide sufficient heat energy to the biological processes of the treatment system. Solar radiation will also be used to evaporate most of the wastewater stream so that the system will be near the vision of zero effluent. The solid residues of this new system will be a fraction of the old system.
- The remaining solid residues will be in the form of hygienized compost that can be reused as fertilizer for local agricultural production. To reuse the nutrients in the wastewater for onsite production of vegetables is a second vision of SANBOX in the Alps.

The practical part of the SANBOX project terminated end of June, 2011. The test of the prototype at the Britannia Hütte was successful with regards to meeting the treatment goals. However, some components needs further development, especially with respect to reduce maintenance needs and to ensure a smoother operation than during the prototype test. The system has therefore been disassembled pending further development. More information will be available on the project website (http://www.sanbox.info/index.htm) after the final evaluation of the project.

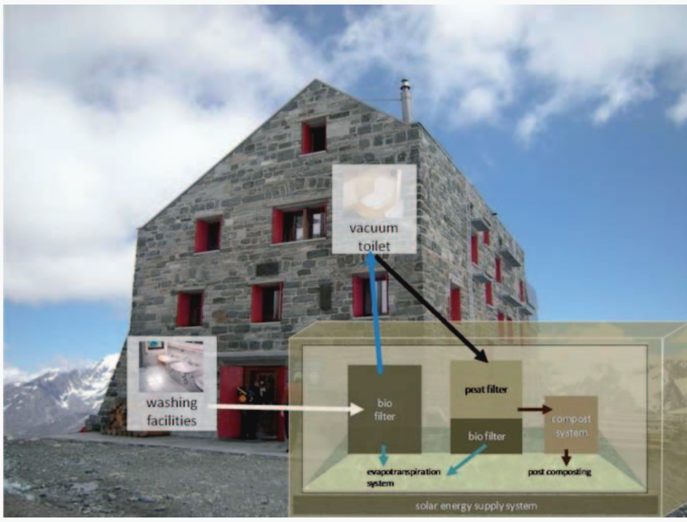

Figure 10: Brittania Hütte and the SANBOX system (Picture: SANBOX, 2011).

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Name: Günter Langergraber
Organisation: BOKU University, Institute of Sanitary Engineering
Town, Country: Vienna, Austria
eMail: guenter.langergraber@boku.ac.at

Name: Elke Müllegger
Organisation: EcoSan Club, Austria
Town, Country: Vienna, Austria
eMail: elke.muellegger@ecosan.at

Sanitation system for the 'Gloggnitzer Huette' mountain refuge

This paper gives information about the feasibility of source separating sanitation solutions for mountain refuges.

Authors: Elisabeth Freiberger, Norbert Weissenbacher

Abstract

The sanitation system of a small mountain refuge situated in a sensitive drinking water catchment had to be adapted to reach appropriate wastewater treatment and disposal. As the refuge is dependent on hand-carried drinking water and photovoltaic energy supplies the energy and water demand of a new system had to be as low as possible. A combination of a composting toilet, waterless urinals and a constructed wetland was foreseen to meet these requirements. Since the mountain refuge is opened at weekends only, peak loads have to be expected. A buffer tank was installed for flow equalisation and greywater storage during winter. With the help of a volume-controlled inflow pump, the greywater inflow can be distributed over a whole week preventing dry-out of the constructed wetland. The effluent of the constructed wetland is discharged in an evaporation bed. To increase the degradation of organic solids in the composting toilet, a solar heat collector is used for ventilation of the composting chamber. The system start up was in spring 2011. It will be intensively monitored and shall serve as pilot for other mountain refuges under comparable conditions.

Introduction

More than 15,000 public and private mountain refuges can be found in the Alps (Grinzinger, 1999). Due to their remote location the infrastructure of mountain refuges are mostly stand-alone systems. An integrated management of energy and water supply, wastewater treatment and waste disposal is needed. Technical support, training, user friendly control and simple system set up are preconditions for a reliable operation of the infrastructure (Weissenbacher et al., 2008). A number of mountain refuges are situated in the catchment area of Vienna's drinking water supply. The hydrogeology is sensitive and therefore the Vienna Waterworks and the water authority demand safe wastewater treatment from objects within the water protection areas to avoid adverse impacts on the drinking water quality.

One of these objects is the Gloggnitzer Huette (GH), see Figure 1. This private refuge was without appropriate wastewater treatment and therefore subject to adaptation during the overall renovation in 2010. The goal of the adaptation of the sanitation system was to treat the produced wastewater to the state of the art under the difficult operation conditions of the refuge. Beside that the water supply should be improved by rainwater use. The main challenges of the project were the wastewater load variations due to the weekend operation as well as the limited energy availability. Due to the fact that the building is not accessible via road transport, helicopter transport was necessary. The Vienna waterworks were closely involved in planning and construction. The aim of this paper is to describe the developed solution to under the specific conditions of the GH.

Technical data:

- Toilet waste treated in composting toilet
- Wastewater produced (greywater, urine and leachate from composting toilets): 110 L/day
- Design load for wastewater treatment plant: 4 person equivalent (p.e.)
- Buffer tank (1 m³) with to equalize flow
- Vertical flow constructed wetland for greywater and urine treatment with 1.25 m² per p.e.
- Final effluent from constructed wetland discharged in evaporation bed (ca. 4 m²)

Figure 1: Overview on the catchment of Vienna Waterworks and the site of the 'Gloggnitzer Huette' (Source: www.wasserwerk.at). Shaded areas mark zones of water protection. Blue lines are the water supply mains of Vienna.

Boundary conditions and basic concept

The mountain refuge 'Gloggnitzer Huette' is located on the mountain 'Raxalpe' in Lower Austria at an altitude of 1548 m. It can exclusively be reached by foot and is opened for guests at weekends in summer and at selected weekends in winter. The capacity is for 22 overnight guests. Up to now, the refuge was equipped with a pit latrine. There is no water supply connection; the water used in the refuge has to be carried by hand from a nearby spring. Power was supplied by photovoltaic panel and battery storage. The whole system is powered in DC mode.

To account for the load variations and the limited power and water availability, a low energy biological wastewater treatment with sufficient buffering capacity and toilet facilities with low water consumption were necessary. It was decided to use a combination of a composting toilet and greywater treatment by vertical flow constructed wetland followed by an evaporation basin. Rainwater harvesting should provide an additional water source.

Legal requirements

Table 1 compares the permits of the 'Gloggnitzer Huette' to other relevant Austrian legal ordinances. Within the legal procedure the requirements for the treated wastewater have been reduced to BOD5 of 15 mg/L and NH4-N of 7 mg/L for the protection of the drinking water catchment in the area. These requirements have been stated by the water authority prior to the detailed technical design of the system. As the refuge is located in the sensitive drinking water catchment permits for Enterococci and E.Coli have been added to the standard parameter set according to the minimum hygienic requirements of the Directive 2007/7/EC (Bathing Water Directive).

Wastewater production

Due to the fact that there is no piped water connection, the water use could not be monitored as foreseen by planning guidelines (OEWAV Regelblatt 1, 2000) or the wastewater emission directive for remote stand-alone buildings (3.AEVkA, 2006). Hence, the wastewater production had to be estimated. Wastewater, i.e. greywater, is generated mainly in the kitchen and the washing room of the refuge. Smaller amounts originate from the waterless urinal and the leakage of the composting toilet. The weekly amounts were estimated based on the operator information as follows:

Under the assumption of operation of the refuge for 40 weekends and 5 public holidays the figures in Table 2 result in a total wastewater volume of 5 m3 per year. It is assumed that the same amount of wastewater is produced on public holidays and weekends. Including a safety margin, a design load of 4 p.e. (as 60 g BOD5/p.e./d) and an average wastewater design volume of 25 litres per day have been selected (175 L/week).

Table 2: Estimation of average wastewater production for weekends and public holidays.

Guests	Wastewater per unit		Total per weekend
6 Overnight	10	L/day	60 L
10 Daytime	5	L/day	50 L
			110L

Table 1: Requirements regarding the urban wastewater treatment directive (1.AEVkA, 1996), the directive for stand-alone buildings in remote areas (3.AEVkA, 2006) and the specific permits for the 'Gloggnitzer Huette'

Parameter	1.AEVkA (1996)	3.AEVkA (2006)	GH Permit (2010)
NH4-N*	10 mg/L	0.9 g/p.e./d	7 mg/L
BOD_5	25 mg/L	12 g/p.e./d	15 mg/L
COD	90 mg/L	36 g/p.e./d	60 mg/L
Enterococci	-	-	330 MPN/100 mL
E.Coli	-	-	900 MPN/ 100 mL

MPN … most probable number (a method for estimating counts of microorganisms)
p.e. … person equivalent
*at wastewater temperatures: >12 °C

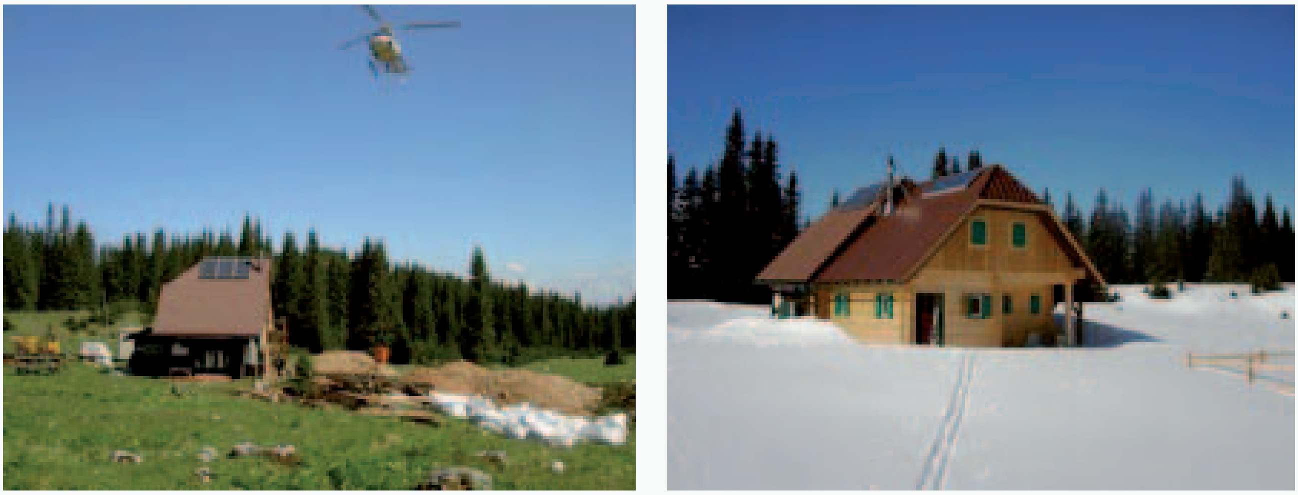

Figure 2: The 'Gloggnitzer Huette' at an early stage of adaptation and renovation - helicopter transport of construction materials in progress (left) - and after the renovation in winter (right).

System design

To reduce the wastewater quantity and solid load a composting toilet is used. This toilet assures that the largest part of organic matter and a significant amount of nutrients is retained away from the wastewater stream. The faeces are stabilized aerobically in the toilet chamber. After a secondary rotting process in composting bags, the compost can be easily transported for disposal to the valley.

There are two toilet seats connected to the composting chamber. Pre-heated air (solar collector at the roof) is piped to the basement where the composting chamber and the buffer tank are situated. Two vents blow the exhaust air from the urinal and the composting chamber to the outside of the building (Figure 3).

Greywater from the kitchen and the washing room as well as wastewater from the waterless urinal and leachate from the composting toilet are collected in a buffer tank of 1 m³. At the inlet of the tank a filter is installed as a pre-treatment to remove solids (Figure 4). Since the wastewater production varies significantly during the week and the year, the tank is used as a flow equalisation to the wastewater treatment plant.

Figure 3: Scheme of the composting toilet and the ventilation (left) and composting chamber (right).

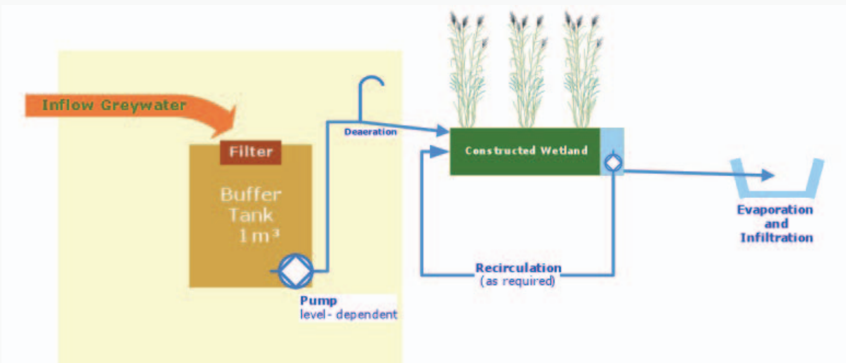

Figure 4: Scheme of the greywater and urine treatment.

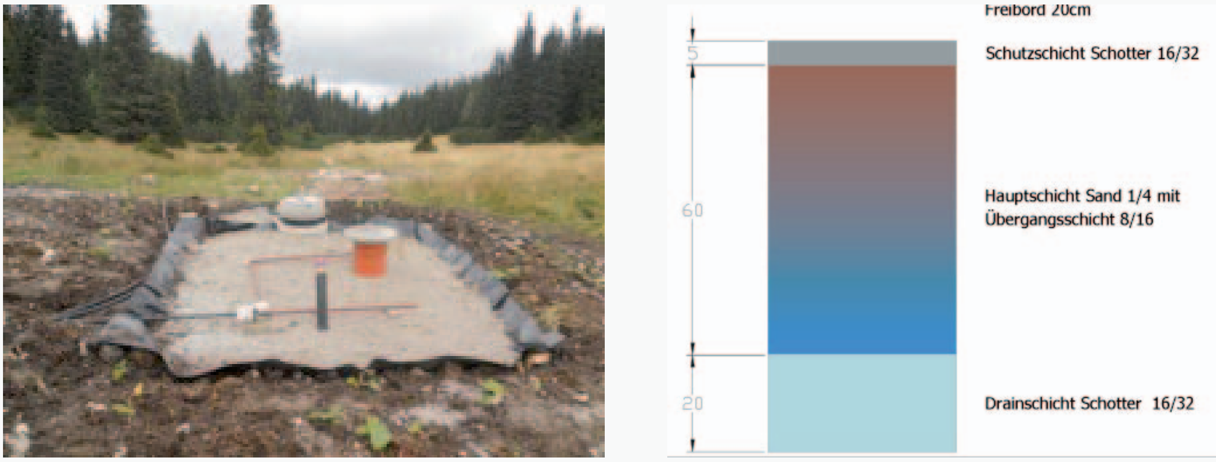

Figure 5: Vertical flow constructed wetland (left) and the layers of the vertical flow bed (right).

Due the effluent ammonia requirements stable nitrification is necessary. Therefore, a vertical flow constructed wetland was selected to treat the greywater from the kitchen and the washrooms, the urine from the dry urinal and eventually occurring leachate from the compost chamber. Normally the Austrian design guidelines foresee 4 m2 of surface area per p.e. for vertical flow constructed wetlands (ON B 2505, 2009). In the case of greywater/urine treatment only, 5 m2 surface area of the vertical flow bed for the estimated average load of 4 p.e. have been considered as sufficient. Overdesign could lead to dry-out and induces unnecessary costly transport by helicopter. The low energy demand and the ability to cope with load variations of constructed wetlands are further advantages of the constructed wetland for this particular application. The constructed wetland and the layers of the gravel filter are shown in Figure 5.

As stated above, the buffer tank prevents load peaks and the distribution of the inflow during non-operating periods (weekdays). The constructed wetland would be otherwise being prone to dry out. The wastewater from the buffer tank is pumped in batches to the treatment depending on the water level to ensure a distributed inflow to the constructed wetland. The volume of the inflow batches decreases with decreasing actual volume of greywater in the buffer tank.

The effluent of the constructed wetland can either be re-circulated to the buffer tank to achieve longer hydraulic retention or flows directly via gravity to an evaporation bed (Figure 4). The evaporation bed with a surface area of ca. 4 m² shall assure that as much wastewater as possible evaporates and only a small amount infiltrates into the ground. Due to the low wastewater volumes that are to be expected and a partial evapotranspiration at the constructed wetland, the bed is expected to lead to a more or less total evaporation of the treated wastewater. In case the performance monitoring shows a need to reduce the hygienic contamination of the effluent, the installation of UV disinfection can be introduced easily in the effluent chamber. The installation of a UV treatment device would lead to significantly increased energy consumption and increased maintenance efforts.

Costs

The investment costs for the overall sanitation system can be split in three main parts:

- Wastewater and solids collection, storage and solids treatment
- Wastewater treatment
- Wastewater disposal

The costs for the composting toilet have been about 1,500 €/p.e. Despite every mountain refuge is unique in terms elevation, water supply, transport and energy supply, a range for investment costs can be given for different wastewater treatment systems. DAV (2011) give a range of 1,800-3,900 €/p.e. for the investment costs of constructed wetlands at mountain refuges. With about 2,100 €/p.e., the Gloggnitzer Huette constructed wetland lies at the lower end of this range for wastewater treatment. Finally, including the construction of the evaporation bed, total investment costs amounted to 4,000 €/p.e. for the whole sanitation system.

Operation and maintenance

The operation and maintenance is carried out by the voluntary personnel of the alpine association owning the place following a schedule for the operating season. The main efforts for maintaining the sanitation system are:

1. Composting toilet: Addition of a handful of sawdust or ashes after every use by the users; addition of bark or hay once a week by the operators. The rotting chamber is emptied when full and the contents are transferred for further degradation in a composting box. Odour and flies indicate a suboptimal operation due to the lack of bulking material or the presence of non-degradable matter or inhibiting chemicals. The operation of the ventilation system is crucial for the operation; the vents can be pre-set manually to provide sufficient air exchange.
2. Greywater treatment: The mode of operation of the inflow pump has to be adapted according to

the greywater production observed in the buffer tank to avoid dry-out of the constructed wetland. To ensure sufficient treatment, the operators have to carry out monthly measurements of ammonia and settle able solids in the plant effluent. Additionally, the ph and the wastewater temperature are to be monitored. Once a year, the plant operation has to be supervised externally. Regular operation contains monthly checks of the plant inflow, its distribution and pipe cleaning when necessary.

All operation and maintenance activities have to be documented. To increase the knowledge on the systems operation the responsible persons of the alpine association attended a two days training seminar on constructed wetlands.

Summary an outlook

The Gloggnitzer Huette is a good example for many small remote private and public buildings in the Alps. The location in a sensitive drinking water catchment requires state of the art wastewater treatment and disposal. The infrastructure has to work reliably under the difficult conditions of low water and energy availability even though no permanent supervision is possible due to weekend operation only. The chosen system combines different technologies often used in ecological sanitation systems (composting toilet and constructed wetland) and adds up technical components like the volume based flow equalisation with the option to store the wastewater during winter time and solar ventilation of the composting chamber. The discharge of the treated wastewater to the environment is reduced by using a separated evaporation bed. Further treatment (UV disinfection) could be easily installed if necessary. The performance of the described system will be monitored closely to reach optimal performance. Proven successful, the system is expected to be implemented at other comparable mountain refuges in the future.

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Name: Elisabeth Freiberger
Organisation: ESC Consulting Austria
Town, Country: Vienna, Austria
eMail: elisabeth.freiberger@ecosan.at

Name: Norbert Weissenbacher
Organisation: ESC Consulting Austria
Town, Country: Vienna, Austria
eMail: norbert.weissenbacher@ecosan.at

Solid Waste management in mountain refuges – results and implications from a case study

Based on a survey of 100 Alpine mountain refuges, this paper describes the current status of solid waste management and deduces recommendations for sustainable waste management.

Author: Sandra Lebersorger

Abstract

Waste management in mountain refuges is characterised by the decentralized position of mountain refuges, difficult transport conditions and the necessity to transport all waste generated to waste collection facilities in the valley. Based upon results from 100 Alpine mountain refuges, this paper describes the current status of solid waste management and provides recommendations, which can be used for other decentralized systems as well. The minimization of waste quantities is a key factor for reducing transport costs, and can be achieved by waste prevention, i.e. measures taken before something becomes waste, as well as by on site composting of biowaste. Attention should be paid to the compliance with legal requirements and the prevention of negative environmental impacts. The results of the project reveal that there is need for information among operators of mountain refuges, in particular with regard to separate collection of hazardous waste, state-of-the-art composting and the illegality of burning wastes.

Introduction

Mountain refuges play an important role in Alpine tourism and local recreation. There are more than 15,000 mountain refuges and inns throughout the Alps, of which approximately 1,600 are owned by Alpine Associations (DBU, 2005). Their location in a sensitive ecological environment, often far away from other infrastructure, difficult transport conditions and sometimes extreme climatic conditions pose a challenge for the supply with water, energy and goods and for the disposal of wastewater and waste. An international project (DAV, 2010; Lebersorger et al., 2011) which was conducted between 2006 and 2010, evaluated the current situation of supply and disposal systems of Alpine mountain refuges and developed guidelines to be applied in the sustainable planning, construction and operation of supply and disposal systems (cf. Deutscher und Österreichischer Alpenverein, 2011). This paper focuses on solid waste management in mountain refuges. The findings presented are based on a detailed investigation of 100 mountain refuges, the majority of which are situated in Austria (70 refuges) and Germany (13) and the others in Italy (8), Switzerland (4) Slovenia (3) and the Czech Republic (2) (for methodological details see Lebersorger et al., 2011).

The examined mountain refuges are situated in countries with predominately well developed waste management infrastructure and existing waste collection systems. Due to the isolated location of mountain refuges – far from other

Key factors for sustainable solid waste management in mountain refuges are:

- Compliance with legal requirements (e.g. no burning of waste, mandatory use of existing municipal collection schemes)
- Minimizing the amount of waste generated - by means of waste prevention and on site composting of biowaste
- State-of-the-art composting (use of covered crates, appropriate application of composting procedures)
- Proper collection and storage of wastes, recyclables and hazardous waste
- Minimizing the number of journeys to be undertaken by minimizing the weight and volume of solid waste and by avoiding empty or partially loaded transports
- Provision of information to operators of mountain refuges and tourists

infrastructure and often difficult to access – all wastes generated have to be transported to waste collection facilities in the valley. This is a basic difference to other buildings whose waste is usually picked up by regular waste collection tours. 19% of the examined mountain refuges could only transport supply goods and waste by helicopter. 34% used a cable car and 47% were accessible via a road. The few available roads are often represented by steep gravel tracks that can only be accessed by means of special vehicles and at certain times. The means of transport represent a crucial factor in terms of costs and climate relevance, with the helicopter constituting the most unfavourable situation. The transportation of goods via cable car implicates the use of fuel-derived energy.

Waste management in mountain refuges should be aimed at sustaining the proper function (offering food, drinks and accommodation to tourists) of the mountain refuge, at avoiding disadvantageous influences on humans and the environment as well as at minimizing waste generation and the amount of waste which has to be transported to the valley. Legislation concerning waste management in Europe and Austria give priority to waste prevention, followed by recycling and finally disposal (Directive 2008/98/EC, BGBl. I Nr. 102/2001). This hierarchy also applies to waste management in mountain refuges and is therefore used for the structure of this paper. Starting with a description of waste generation and composition, measures for waste prevention in mountain refuges are presented, followed by waste collection and finally ways of disposal. The basic principles and findings presented in this paper can also be adopted for other regions including developing countries.

Waste generation

Mountain refuges are very heterogeneous which is exemplified by the survey of 100 mountain refuges. They differ in:

- Management (without staff / with staff) covering a range from 0 to 20 employees
- Seasonal operation (all over the year / summer / winter) covering a range between 70 and 365 days a year
- Frequency of visitors: daytime visitors (the average number ranges from 3 people to several 100 per day), overnight stays (average from 0 up to 100, maximum up to 370 people per day)
- Number of beds (from 5 to 342)
- and comfort (with/ without showers; from simple shelters to restaurant for day-trippers).

The Alpine Associations distinguish 3 classes of mountain refuges: shelters, which are only accessible by foot after at least a one hour´s walk, with very simple facilities and a small variety of offered food and drinks (category I); mountain refuges in touristic areas, usually open all over the year, offering a wider range of food and beverages and more comfort (category II); mountain refuges with mainly daytime visitors, which are accessible for tourists by mechanical means of transport (e.g. cable-car, car) (category III) (Grinzinger, 1999).

The quantities and composition of waste differ accordingly. Main sources of waste generation are meal preparation (preparation residues, leftovers, fats,…), packaging (such as cans, bottles, bags, boxes etc. made of plastics, metal, glass, cardboard), hygienic paper (napkins, paper towels,…), waste brought by visitors (packaging, leftovers, sanitary products,…), waste from the staff resident in the mountain refuge (typical household waste), waste from water and energy supply and wastewater treatment (residues from operating materials, packaging, chemicals, batteries,…). Furthermore, also bulky waste, waste electric and electrical equipment, textiles etc. can occur.

Waste quantities of the 100 examined mountain refuges show a wide variation, so that only rough estimates can be provided. The average waste quantity per employee and month was 61 kg (Lebersorger et al., 2011). Estimates for the average waste quantity per visitor per day amount between 0.110 kg (Lebersorger et al., 2011) and 0.200 kg per day (Grinzinger, 1999).

Waste prevention

Waste prevention means measures taken before a substance, material or product has become waste, that reduce the quantity of waste, the adverse impacts of the generated waste on the environment and human health; or the content of harmful substances in materials and products (Directive 2008/98/EC). Preventing waste before their generation can significantly reduce the quantity of waste which has to be transported from a mountain refuge to the valley. Measures include the avoidance of single-portion packs, paper towels and paper napkins, the use of reusable packaging instead of disposable packaging, the use of larger packaging units or the use of unpacked products if possible. Table 1 shows the number of operators who referred the application of prevention measures.

Table 1. Percent of mountain refuge operators referring the application of various prevention measure

measure	%
avoidance of single-portion packs	27
avoidance of cans	26
avoidance of paper towels/ napkins	11
avoidance of disposable packaging	71
no provision of bins for visitor waste	32
provision of bins for visitor waste in lavatories alone	35

Waste generated by visitors contributes towards an increase in total waste quantities, and is a frequently reported problem (Grinzinger, 1999). 13% of the interviewed operators of mountain refuges complained of problems with visitor-generated waste. Visitors are asked to take all products, items and related wastes (e.g. food packaging, leftovers, tissues) which they brought with them back to the valley for disposal. Alpine Associations provide respective information on their websites, and a lot of mountain refuges inform their visitors by means of signs in or outside the mountain refuges or directly verbally. Only 15% of the examined mountain refuges did not provide any information. Figure 1 shows some examples.

An effective measure for the prevention of visitor-generated waste is to provide no bins for visitor waste. The case study in 100 mountain refuges showed that the lower the number of bins made available to visitors, the lesser the quantities of waste generated (Lebersorger et al., 2011). About one third of the mountain refuge operators interviewed provided no waste bins for visitors; another third provided bins only in lavatories (see table 1) and the remaining third provided bins at strategic points throughout the premises (e.g. in the restaurant, in the entrance hall, on the floors or in dormitories). It is recommended to provide a waste bin in the lavatories. Otherwise some visitors will dispose of waste into the toilets, which can cause severe problems in the wastewater treatment system. 6% of the interviewed operators reported relevant negative experience. According to estimates, waste generated by visitors accounts between 20% and 70% of the waste volume (Grinzinger, 1999) and about 35% by weight of total waste quantity of a mountain refuge (Lebersorger et al., 2011). Therefore it can be assumed that the provision of waste bins only in lavatories and consequent information of the visitors can reduce waste quantities at up to one third.

Figure 1: Information telling tourists to take along their waste and dispose of it in the valley: with additional provision of garbage bags (left), poster inside a mountain refuge (top right), sign with bilingual information (bottom right) (photos IEVEBS)

Waste Collection

According to national legislation, wastes have to be collected and treated separately in the countries which were involved in the project. For example Austria has separate collection schemes for residual waste, biowaste, packaging (plastics, composite materials, glass, metals, paper and cardboard), hazardous household waste and a lot of other types of waste such as waste electrical and electronic equipment or bulky waste. A fee has to be paid for residual waste and biowaste, whereas recyclables such as plastics, metal or paper usually can be disposed of for free at municipal waste collection facilities. Therefore, operators of mountain refuges can save costs by trying to minimize the quantity of residual waste and collecting recyclables separately.

Recycling is beneficial for the environment because of saving energy, greenhouse gas emissions, resource consumption and landfill volume. For example, the use of glass waste in the production of glass results in energy savings of up to 22.5%, and by using 1 metric tonne of cullets for glass production, 5 metric tonnes of sodium carbonate can be saved (Tiltmann, 1993-95 cited by Lechner, 2004). Recycling aluminium saves 95% of the energy which would be necessary for the production of primary aluminium (Lechner, 2004).

The survey of the selected mountain refuges showed that the majority of operators collected recyclables and biowaste separately. As for hazardous waste the situation was not as good. Only 28% of the operators interviewed reported the separate collection of hazardous waste. Smaller refuges separate hazardous wastes to a significantly lower degree than larger refuges (Lebersorger et al., 2011). Hazardous waste comprises chemicals (cleaning agents, chemicals used for the operation and maintenance of supply and disposal systems, drugs), mineral oils and oily wastes, batteries and coating materials. They require separate collection, storage and special treatment (BGBl. I Nr. 102/2001), because their improper treatment (e.g. by means of landfilling) can have negative consequences on the environment (water, air, soil), plants, animals and on human health. Also waste electrical and electronic equipment requires separate collection and treatment due to hazardous components (Directive 2002/96/EC). In order to remedy information gaps and incorrect handling of hazardous waste, specific information should be provided to the operators of the mountain refuges.

In the kitchen, waste should be collected and stored in firm bins with lids and should be removed from the working area at least once a day (Bundesministerium für Gesundheit, Familie und Jugend, 2007). Figure 2 (left picture) shows a positive example of storage containers in the kitchen of a mountain refuge. Until wastes are transported to the valley, they should be stored in sufficiently dimensioned, enclosed rooms or containers in order to prevent exposure to rain, wind and animals (DAV, 2010, Grinzinger, 1999). It is obvious that wastes should not be stored in the water supply catchment area (DAV, 2010). Plastic bags should only be used for wastes which pose no risk of injury; that means e.g. for paper, cardboard or plastics packaging, but not for glass or hazardous waste (Bundesministerium für Gesundheit, Familie und Jugend, 2007). Figure 2 (right picture) shows a positive example for separate waste collection using different containers. The survey revealed that wastes are not always collected and stored in an optimal manner and that there is potential for optimization.

Waste presses or can presses are sometimes used in mountain refuges in order to reduce waste volumes and accordingly the volume of waste for transport. As can be seen in figure 3, different types of waste presses are used: from very simple, self-made and hand-operated solutions to complex electrically driven presses. Some aspects have to be considered, here. As the use of waste presses is restricted by laws in some regions, it has to be checked in advance if a compaction of waste is allowed and to what extent, respectively. Electrically driven presses could be disadvantageous at mountain refuges with difficulties in energy supply. In Alpine mountain refuges, energy is often scarce and can only be produced at high costs. In any case, folding cardboards, and compressing plastic bottles and cans by hand is recommended as an easy and simple means to reduce waste volumes and to avoid squandering transport volume.

Figure 2: Separate collection of wastes in the kitchen (left side) and in a storage room of a mountain refuge (right side) (photos IEVEBS)

Figure 3: different kinds of waste presses used in mountain refuges: simple press for cans (left), hand operated waste press (middle), electrically driven press (right) (photos IEVEBS)

Figure 4: Positive examples for composting (photos IEVEBS)

Ways of waste disposal

As all waste generated at a mountain refuge has to be transported to collection facilities in the valley, there are no other legal ways for disposal for mountain refuges, except for composting on site. In municipal waste management schemes waste is further treated in incineration plants, by mechanical biological pre-treatment, composting, anaerobic digestion, recycling, etc. – according to waste type and the existing facilities in a region. Waste transport from mountain refuges can cause significant costs according to the position and accessibility of the refuge. The number of journeys to be undertaken should be optimized by avoiding empty or only partially loaded trucks.

An effective opportunity to reduce the amount of waste for transport is the composting of biowaste on site, provided that the requirements for controlled composting are met. Composting is the low-loss decomposition of organic compounds and the conversion to stabile humic-substances under aerobic conditions (Lechner, 2004; for details about composting in developing countries see e.g. Linzner and Wassermann, 2006; Linzner, 2010). Alternatively, bio-waste can also be composted in the course of wastewater treatment, together with sewage sludge or brown waters by means of anaerobic digestion. Based upon the results from the survey in the 100 mountain refuges, it is estimated that on site treatment of biowaste can lead to a 20% to 25% reduction by weight of the waste quantity for transport (Lebersorger et al., 2011).

A total of 73% of the 100 mountain refuge operators interviewed referred to treating some degree of biowaste on site by composting or feeding to animals. However, only 1 out of 5 composted biowaste in an appropriate manner by using crates (see figure 4). The others applied no specific composting procedure, simply placing biowaste on a heap or throwing it into a hole in the ground (figure 5), neither of which met the requirements for controlled composting. This rather corresponds to littering than to composting.

Figure 5: Negative example for "composting": This is simply littering, no composting (photo IEVEBS)

Biowaste should not be fed to animals. On the one hand there are legal regulations in the EU and in Austria (RGBl. Nr. 177/1909, BGBl. I Nr. 141/2003) which extensively prohibit the feeding of kitchen waste, particularly those containing animal by-products, to domestic animals and wildlife. On the other hand, feeding wildlife interferes with their natural living conditions and can influence ecological balance in a sensitive environment. Animals such as jackdaws might benefit from a higher food supply in an otherwise scarce environment. However, also problems arise. The example from countries like Canada or the US show that bears which have access to waste from humans lose their innate diffidence and instinctive fear of humans, which leads to the onset of unpredictable dangerous behaviour when encountering humans (Schneider, 2009). Studies also found that bears feeding on human waste had only half the life expectancy of wild bears (NPS, 2008 cited by Schneider, 2009).

Biowaste should only be composted according to the state-of-the-art and if the conditions (such as altitude, weather conditions, legal framework) permit composting. Composting should take place in a stable, naturally aerated crate with a cover as protection against rain, drying-up and animals. The crate should be easily accessible and should be positioned in a partly shadowy place. A regular maintenance is necessary (proper feedstock mixture, periodical turning) (Grinzinger, 1999). After the composting process, the compost may be disposed of in the area surrounding the refuge, if not prohibited by legal provisions, or failing this, should be transported to the valley. If composting on site is not an option, biowaste should be collected separately so that they can be further processed in existing decentralized or centralized composting plants or anaerobic digestion plants in the valley.

Though illegal in Austria, 36% of the 100 operators interviewed reported that they burned certain types of waste, particularly paper and cardboard, but at times also plastics. According to Austrian legislation, wastes are only allowed to be burnt in officially approved plants. The burning of waste in heating systems is prohibited. Therefore only small amounts of paper and cardboard may be used to facilitate the lightning of a fire. The combustion of household waste constitutes a major source for high poly-chlorinated dibenzo-p-dioxins and -furans (PCDD/F) emissions (Hübner et al., 2005). PCDD are persistent organic pollutants which accumulate in soil, plants, animals and in human bodies. They have adverse effect on the human immune system and ability for reproduction, and are suspected of causing cancer (Umweltbundesamt, 2010). In order to prevent the uncontrolled burning of waste for the future, intensified information of the operators of mountain refuges is necessary.

Recommendations / conclusion

Waste management in mountain refuges is characterised by the decentralized position of mountain refuges, difficult transport conditions and the necessity to transport all waste generated to waste collection facilities in the valley. For this reason, all kinds of measures which reduce the amount of waste for transport are very important. Waste quantities can be reduced by means of waste prevention (e.g. prompting visitors to take their waste back to the valley, avoidance of single-portion packs and paper towels, using returnable instead of single-serving packaging), but also by means of on site composting of biowaste. A measure which reduces the volume of waste but does not influence mass is the use of waste compactors and can presses. Many of the investigated mountain refuges are using different strategies for waste reduction. In terms of transport costs, the number of transports should be optimized by avoiding empty or only partially loaded trucks.

However, investigations of 100 Alpine mountain refuges showed that some operators of mountain refuges also chose unfavourable ways to get rid of their waste. Although prohibited by law, paper and cardboard as well as some plastics are burned in heating systems of some mountain refuges, and composting is not performed in an appropriate manner by the majority of operators. Such measures reduce waste quantities for transport at the expense of negative environmental effects and non-compliance of legal regulations, and should therefore be refrained from.

The results of the project reveal that there is need for information among operators of mountain refuges, in particular with regard to separate collection of hazardous waste, state-of-the-art composting and legal requirements.

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Name: Sandra Lebersorger

Organisation: BOKU University, Institute of Waste Management

Town, Country: Vienna, Austria

eMail: sandra.lebersorger@boku.ac.at

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