Science of the Total Environment 650 (2019) 1759–1770

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Reuse of materials from a Sustainable Drainage System device: Health, Safety and Environment assessment for an end-of-life Pervious Pavement Structure

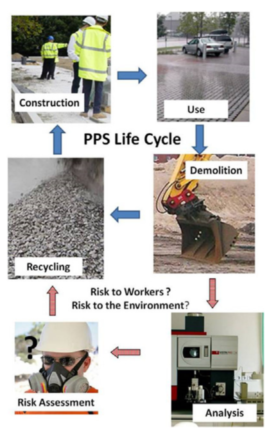
F.U. Mbanaso [a,*], S.M. Charlesworth [a], S.J. Coupe [a], A.P. Newman [b], E.O. Nnadi [c]

[a] *Centre for Agroecology, Water and Resilience (CAWR), Coventry University, Coventry, UK*
[b] *Centre for the Built and Natural Environment Research, Coventry University, Coventry, UK*
[c] *GITECO-UC, Univ. of Cantabria, Avda de los Castros s/n. 39005, Santander, Spain*

HIGHLIGHTS

- No potential adverse health impacts associated with occupational exposure to benzene, toluene, ethylbenzene and xylene.
- No potential health effects from exposure to leachates which may be reused.
- Carcinogenic and non-carcinogenic risks significantly below the regulatory limits.
- PPS demolition wastes may be re-used and recycled as aggregates.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 4 July 2018
Received in revised form 16 September 2018
Accepted 17 September 2018
Available online 26 September 2018

Editor: Xinbin Feng

Keywords:
Sustainable Drainage System
Pervious Pavement System
Occupational Health
Environmental Health
Gas Chromatography (GC) with Flame-Ionization Detection (GC/FID)
inductively coupled plasma (ICP) spectroscopy
Sustainability, Waste Management

ABSTRACT

Pervious pavement systems can have a life span of about 20 years but, at end-of-life, it becomes necessary to evaluate the state of the infrastructure to determine whether they pose a health and safety risk to workers during dismantling, and also determine potential reuse of the waste material generated. In this paper, we report of an investigation conducted to evaluate whether Pervious pavement systems are hazardous to human health at end-of-life and also to assess the mobility of the stormwater pollutants trapped in the system as a measure of their potential release to receiving systems such as water-bodies and groundwater systems. After decommissioning, the pervious pavement structure was sampled for analysis including Gas Chromatography, inductively coupled plasma spectroscopy and, leachate analysis. Results show that carcinogenic risks were significantly below the regulatory limit of 1×10^{-6} while, the hazard quotients and cumulative hazard indices were also below regulatory value of 1, based on United States Environmental Protection Agency standards. Furthermore, mean concentrations of benzene, toluene, ethylbenzene and xylene were significantly less than the UK soil guideline values. The results of the leachate analysis show that the metals of concern, Pb, Zn, Cr, Ni, Cd and Cu were all below the threshold for reuse applications such as irrigation purposes as they were all below the regulatory limits such as Food and Agriculture Organization and, United States Environmental Protection Agency standards. Finally, the evaluation of potential reuse and recycling purposes indicate that wastes generated

* Corresponding author.
E-mail address: mbanasof@uni.coventry.ac.uk (F.U. Mbanaso).

https://doi.org/10.1016/j.scitotenv.2018.09.224

from the dismantling of the PPS are within limits for recycling as aggregates for other civil engineering projects as per European Union standards. This has potential to enhance UK's drive to achieve the target of 70% level of construction & demolition waste recovery for reuse and recycling by the year 2020 as per European Union Water Framework Directive.

1. Introduction

Sustainable Drainage Systems (SuDS) mitigate the environmental risks of urban runoff and the damage done by associated contaminants. So-called hard SuDS, such as Pervious Pavement systems (PPS) are designed to infiltrate and attenuate stormwater runoff to underlying layers of their structure. PPS also provide a suitable platform for car parking, pedestrian and vehicular traffic. The treated stormwater in the PPS is then gradually released to receiving natural water systems or channelled to constructed receiving systems such as storage tanks. In addition to the infiltration and detention of runoff to prevent flooding, it is well known that PPS also treats stormwater for the improvement of discharged water quality in order to protect receiving natural water systems (Shuttleworth et al., 2017; Mbanaso et al., 2016; Pratt et al., 1999). This cleaning function is an issue that generates the potential for stormwater reuse. Although the entire system works together to detain and treat stormwater before controlled discharge downstream, the polypropylene geotextile component has been identified as site of dense pollutant retention and biodegradation of pollutants (Bond et al., 1999; Newman et al., 2006; Mbanaso et al., 2014). The treatment processes which occur within the PPS structure include filtration of contaminants, adsorption onto surfaces, biodegradation by microbes and sedimentation of particulates. Some of the pollutants include heavy metals, hydrocarbons, nutrients, emerging organic contaminants and priority substances, which are all of environmental concern.

The geotextile fibre provides a conducive environment for pollutant degrading microorganisms to thrive by using trapped pollutants to form biofilms. A biofilm is an aggregate of microbes in which the cells of microorganisms stick together to become ingrained within a self-produced matrix of extracellular polymeric substance (Mbanaso et al., 2013). Scanning electron microscope (SEM) analysis of the biofilm structure found on geotextiles fibre of a PPS has shown a diverse community of microbes consisting of bacteria, fungi, protists and metazoans (Coupe, 2004). The retention and removal of contaminants through natural processes protect receiving water bodies (Bond et al., 1999; Coupe, 2004). Water discharged from a PPS or stored in the system for reuse is a potential source of irrigation water and other reuse applications such as fountain refill and flushing of toilets etc. (Nnadi et al., 2009; Mbanaso et al., 2016). However, after several years in service, pollutants and toxins can become trapped in the PPS and accumulate (Charlesworth et al., 2017). Previous research (Pratt, 2001) has expressed concerns over the pollutants that accumulate in these SuDS devices as contaminants which are either non-biodegradable or could not be completely degraded before the structures are dismantled, could leach from the device and may reach receiving water bodies. Furthermore, the potential risk posed by these substances such as hydrocarbons and heavy metals may become compounded because contaminants which were previously thought to be non-hazardous may become hazardous due to physico-chemical and biological reactions prevalent in the PPS system over many years. Also, water quality standards have been included in UK regulations as a result of the Water Framework Directive (EC, 2000). In order to achieve the Environmental Quality Standards required, the potential of SuDS are being increasingly harnessed. As SuDS receive contamination typically associated with road traffic and urban environments, the long-term accumulation of contaminants could potentially classify material as hazardous, an important consideration when undertaking maintenance procedures for operatives handling it, and when decisions have to be made about its eventual disposal. There is potential for the accumulated material to become hazardous to both human and environmental health. This may put the health and safety of workers at risk, especially those who handle such materials during maintenance, processing prior to disposal and others at disposal sites. Workers' Rights include the right to work in conditions that do not pose a risk of serious harm as well as provision of effective training about workplace hazards and control measures. According to Hughes and Ferrett (2009), demolition works is one of the most hazardous construction activities which have been found to be responsible for more deaths and major injuries than other construction operations. The impact of demolition works is not restricted to the immediate environment or site but, also involves the surrounding areas such as adjacent structures, people or passers-by and the milieu. For instance, in terms of volume, it is estimated that Construction and Demolition (C&D) waste constitutes the largest waste stream in the EU as it represents approximately a third of all waste generated (EU, 2016). Thus, efficient management of C&D waste is required as it potentially has several benefits in terms of sustainable development and improved quality of life. It also has potential to increase demand for C&D recycled materials and a major boost for the construction and recycling industry.

However, one of the major hurdles to re-using and recycling C&D waste is the lack of confidence in the quality of C&D recycled materials (EU, 2016). There are also concerns about potential health risks associated with C&D waste. These issues limit and impede the utilisation of C&D waste and the development of the recycling industry. It is therefore, necessary to determine whether it is sustainable to dispose of these SuDS devices after dismantling them via re-use, recycling or other sustainable initiatives. It may well mean that the cost of disposal may be mitigated by the reclassification of the waste. Thus, there is the need for screening waste materials to accurately determine toxicity and prediction of the environmental fate of contaminants as hazardous waste regulations have become more stringent. Although PPS manage the environmental risks of urban runoff and encourage environmental enhancement particularly in car park areas, literature on the long-term resilience to the pollutants they store is scarce as well as information on their effectiveness at end-of-life. In this context, end-of-life is defined as the phase when the PPS which was previously in service, was dismantled.

There are studies which have demonstrated that a PPS can function satisfactorily without any maintenance for over 10 years (Pratt, 2004; Schlüter and Jefferies, 2001; Wild et al., 2002) and over 20 years (Imbe et al., 2002). Table 1 shows recommendations by various stakeholders and practitioners for PPS replacement or reconstruction in part or whole.

Different monitoring initiatives have been carried out, focusing on different parameters and performance indicators. Although a few of the studies have evaluated the performance of the PPS system at end-of-life, such as the hydrological performance (Sañudo-Fontaneda et al., 2018); pollutants retention (Newman et al., 2011); pollutants biodegradation (Mbanaso et al., 2013), none has assessed the potential occupational health and safety impacts at end-of-life as well as the sustainability of the waste disposal after dismantling. There is currently no documented field study on the state of a PPS several years after field operation in terms of efficiency and hazardous nature of the pollutants. Although PPS are efficient at trapping pollutants, it is not known how long the accumulation of these pollutants will take to affect the treatment efficiency of PPS and therefore, one of the design life criteria.