From European to regional management of mining waste deposits: adapting to Walloon specificities

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Abstract. A pre-selection protocol was provided to EU-member states in order to initiate the inventory of the risks associated to closed mine waste facilities, as required by Directive 2006/21/EC. The document is designed as a guidance protocol based on a series of simple criteria that is general enough to be applicable at the European scale but that can be adapted to regional conditions. The pre-selection protocol enables the identification of closed waste facilities that might be at risk from the list of all known closed (and/or abandoned) facilities. Risk assessment is conducted considering the Source, Pathway and Receptor components, based on data that is or is assumed to be readily available. In this paper, a practical implementation of the protocol into a Geographical Information System (GIS) is proposed and a first test-case application to the Walloon Region of Belgium is presented. Criteria that need to be removed from the analysis of the test case are identified (contents in pollutants and groundwater) and criteria based on threshold values that need to be adapted to the specific regional-scale situation are discussed. In their current forms, the surface, population and agriculture criteria lead to include 85 %, 98 % and 100 % of existing sites for further investigation, respectively. Risks associated to transmission by Air or Direct Contact lead to conclude that about 75 % of the heaps do no threaten human health or the environment.

Keywords. Mining waste, EU directive, Walloon Region, Risks, Impacts.

1. Introduction

1.1. The Mining Waste Directive (MWD)

The mining industry has since long produced vast amounts of waste, most of it being still located on sites where all mining activities have ceased. Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the management of waste from extractive industries, often referred to as the "Mining Waste Directive" – MWD, requires in Article 20 that "Member States shall ensure that an inventory of closed waste facilities, including abandoned waste facilities, […] which cause serious negative environmental impacts or have the potential of becoming in the medium or short term a serious threat to human health or the environment is drawn up and periodically updated".

The Ad-hoc Group (AHG) of the Technical Adaptation Committee of Directive 2006/21/EC has been created to facilitate the implementation of Article 20 of the Directive by Member States by 2012. This AHG produced a guidance document [1] describing a pre-selection protocol based on a series of simple criteria.

The pre-selection protocol enables the identification of closed waste facilities that might be at risk from the list of all known closed (and/or abandoned) facilities. Risk assessment is conducted considering the Source, Pathway and Receptor components, based on data that is or is assumed to be readily available. Such data include topographic data (location of settlements, surface waters, terrain, …), census data, data on protected areas, land use/land cover data, data on groundwater

bodies (according to the Water Framework Directive), and site data that are specific to the waste facilities under consideration (location, contents, geometry, …).

The pre-selection protocol is only a first step towards the creation of the inventory requested by the directive. In a second step, in order to identify the closed facilities that actually need to be included in the inventory, further studies are needed in order to improve the characterization of the potential threats that they represent to human health and the environment. Hence, the pre-selection protocol is designed so that its methodology is general enough to be applicable to all facilities throughout Europe. It is also based on a principle of precaution: sites where the relevant information is missing must be included in the pre-selection. However, the AHG recognizes that local specificities should be taken into consideration when conducting the inventory. Stanley et al. (2011) mention that particular implementations must be "appropriate to national circumstances" and suggest changing the proposed threshold values and adding/removing criteria if needed.

This paper describes an implementation of the pre-selection protocol within a Geographical Information System (GIS) framework and its application to the Walloon region of Belgium. This preliminary application allows the identification of the criteria that must be excluded from the analysis and of those that cannot be directly applied as proposed in the protocol. It sets the basis of a reflection that needs to be conducted with the authorities of the Walloon Region in order to establish the inventory required by the MWD

1.2. Test case in Belgium: the Walloon Region:

The direct application of the pre-selection protocol to the Walloon region is hindered by two important impediments. The first one results from to the early historical and geographical development of the mining industry in Belgium. The Belgian coal industry started in the 17th century and had its main exploitation phase during the industrial revolution in the 19th century. In 1905, Belgium was the fourth coal producer in the world [2]. While the Walloon Region was one of the first industrialized regions in continental Europe and has been the economic core of the country until the 60s, it is now dealing with the closure of this sector. As it is also the case in other industrial countries, the mining situation is mostly unknown before the middle of the 20th century [1]. As an example, geochemical information is missing for most closed mining facilities in the Walloon Region. Given the precautionary principle, such facilities cannot then be screened out and the strict application of the protocol leads to evaluating the presence of pathways and receptors. About one thousand waste heaps are listed in the Walloon Region, mainly localized in the valleys of the Sambre and Meuse rivers (Sillon Sambre et Meuse, in French), covering a territory of only about 1000 km2. This area also concentrates two-third of the population of the region. With the default threshold values proposed in the protocol, the resulting risks will be deemed to be high for most closed facilities, and one will need to consider them for further investigation. In that case, the protocol fails in its objective of decreasing the number of facilities needing deeper risk assessment.

The second problem lies in the principle of the additionality of the protocol. Each criteria, either relating to the source, the pathways, or to the presence of receptors, is equally weighed in the global assessment of the level of risk. While such approach allows an easy comparison of the various situations across Europe, it appears that a more nuanced approach is required in order to reach an accurate characterization of the levels of risks at the regional scale. In the Walloon Region, human populations are mostly concentrated near former mining industrial zones. While the proposed threshold distance for the perimeter where populated cores have to be sought could be decreased as it currently leads to include most of the Walloon Region (see section 3), it is agreed that the proximity of populated cores to closed mine waste facilities is a key criterion in the protocol. On the other side, the proximity of protected environmental areas is not seen as a problem for Belgian waste heaps. On the contrary, some of them now welcome rare bird populations or protected vegetal

species and the creation of a protected area would not have occurred without the presence of the waste heap itself. Currently, 11% of the waste heaps listed in the Walloon Region are located in or in the direct vicinity of a Natura 2000 site.

2. Methods

2.1. Protocol flowchart:

The guidance protocol provides a detailed flow chart with all the questions to be addressed in the national test case area [1]. It also describes the rationale, sources of information, responses and consequences of a particular response. A summary of the flow chart is provided in Tab. 1. As discussed in section 1.2, information is generally missing for the first three criteria addressing the chemical quality of the waste material. Walloon authorities never registered serious incidents in the past. However, most of the former Walloon mining sites have been reconverted to other industrial activities and the current threats to human health or the environment are mostly linked to the presence of pollutants arising from the current activities. The first three criteria were then removed from the first step of this analysis. This hypothesis will be validated in the second one and only source stability, pathways, and receptors are considered in section 2.2.

Table 1. Pre-selection criteria.

Contents in pollutants	Sulphide minerals
	Heavy metals
	Dangerous chemicals
Stability of the source	Surface is greater than 10,000 m²
	Height is greater than 20 m
	Slope of foundation is greater than 1:12
Pathway	Water course within 1 km
	Groundwater and high permeability layer
	Air contamination
	Direct contact (uncovered)
Receptor within 1 km	Human settlement of more than 100 people
	Quality status of water body
	Natura 2000 sites
	Agriculture or livestock

The pre-selection protocol for screening closed waste facilities possesses at least the following characteristics: (i) be risk-based (i.e. considering serious environmental impact and serious threat to human health), (ii) be simple, (iii) use readily available data, (iv) address information uncertainty, and (v) be reasonable for the task [1]. Data is assumed to be readily available in each Member State at a 1:100 000 scale. Stanley et al. (2011) refer to well-known datasets such as the Shuttle Radar Topographic Mission (SRTM)1 with a 1:100 000 scale or CORINE2 Digital land use/land cover (LULC) maps at the same scale. The resolution of these datasets is significantly lower than that of the local datasets available for the Walloon Region. This should be kept in mind while selecting the elements at risk.

[1] http://srtm.csi.cgiar.org/

[2] http://www.eea.europa.eu/publications/COR0-landcover

2.2. Data:

The geolocalisation of the waste heaps listed in the Walloon Region is stored in a dataset called « terrils » provided by the Subsurface/Geology Unit of the DGO3 (Direction Générale Opérationelle Agriculture, Ressources naturelles et Environnement - General Directorate of Agriculture, Natural Resources and Environment) of the Walloon Region. This dataset contains 591 occurrences of waste heaps, 417 of them being still visible on the field and 174 of them referring to heaps that were removed in the past and that are not visible anymore.

2.2.1. Stability of the source:

Stability of the source only needs to be taken into consideration for existing waste heaps. Hence, only the 417 corresponding occurrences in the "terrils" database are accounted for here. The larger and higher a waste heap, the more likely it is to cause damage to humans or the environment should it fail. Thresholds are proposed in Tab 1. The surface of the 417 waste heaps is extracted from the geographical information system (ArcGis, ©ESRI). For the height, a digital surface model (DSM – MNT in French) at a 10 m resolution called "Erruissol" has been provided by the DGO3. The height of the heap is calculated from the difference between the mean elevation of the base of the heap and the maximum elevation of the heap.

The third criterion refers to the slope of the foundation upon which the waste heap rests. It was computed based on the elevation of the points at the border of the base of the waste heap, extracted from the DSM. A plane was fitted through these points as an approximation of the natural topography before installation of the waste heap. The mean slope of this plane is retained for the evaluation of this criterion.

2.2.2. Pathways:

Surface water is one of the pathways by which the source material may come into contact with humans or the environment [1]. Surface waters are a source of drinking water for humans and animals while they also contain ecosystems in their own right and support aqueous habitats. The database of the hydrographical network was also provided by the DGO3 and only main courses (navigable or not) are taken into consideration to match with the resolution criteria proposed by Stanley et al. (2001) (see section 2.1). It must be noted that this dataset includes 3000 km of water courses, while the Corine LC dataset only includes 180 km of water courses (Fig. 1).

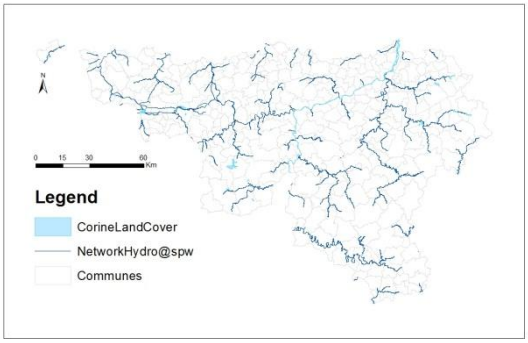

Figure 1. Comparison between Corine and DGO3 dataset.

The groundwater criterion is not found to be relevant at the scale of the Walloon Region. All Walloon waste heaps date back to at least the first half of the 20th century, when environmental protection was not a concern. The absence of any underlying artificial impermeable layers can thus be ascertained. In the current state, we do not have information allowing one to assess the presence of a natural impermeable barrier protecting groundwater resources. However, no link can be made

between the quality of the groundwater resources and one particular waste heap as the relative sizes of the groundwater bodies and the waste heaps are in a ratio of 2 per 1000 (Fig 2). While it is agreed that the whole history of mining at a regional scale can be a cause of low water quality, the impact of one heap is out of proportion (see section 2.2.3).

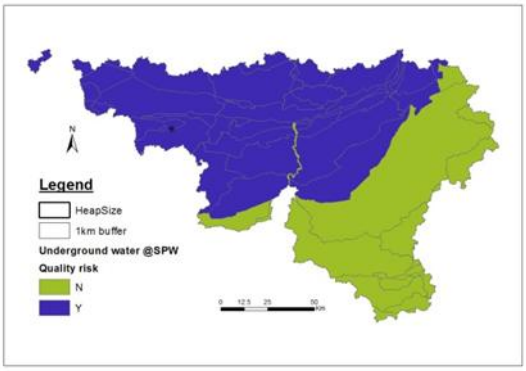

Figure 2. Size comparison between heaps and underground water (@SPW).

The two last criteria of contamination through air or direct contact are analyzed with the same approach; the coverage of the heap. In the case of air contamination, wind may lift up and transport material (dust) and bring mine waste into contact with humans and animals through inhalation. In the case of direct contact, humans or animals can touch the waste present within the facility if it is not covered, for example by water, by vegetation or by some other material. From a practical point of view, Stanley et al (2011) propose to measure the percentage of coverage by vegetation or other covering material. USGS TM landsat 7 images have been used to provide an exhaustive coverage of the Walloon Region. They have a 30 m resolution and 8 bands. Red and near-IR bands are used to produce an NDVI (Normalised Difference Vegetation Index) [3]. This index is classified by a maximum likelihood classifier and the total number of pixels covering each heap is calculated using a zonal statistics within the GIS software.

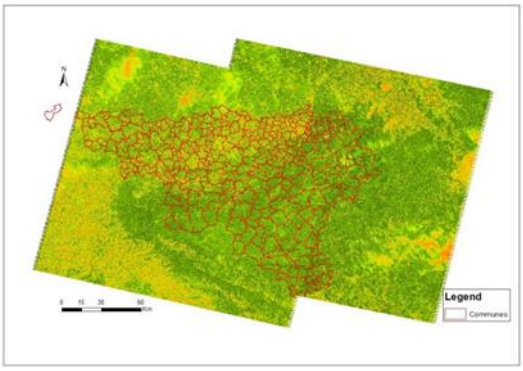

Figure 3. NDVI mosaic from Landsat (@USGS)

2.2.3. Receptors within 1 km:

The more people live in a given area, the more likely someone will come in contact with the waste with potentially harmful effects via one of the four pathways. The disaggregated population dataset is provided by EEA (European Environmental Agency) and produced by DG JRC – Joint Research Center [4]. This dataset integrates population statistics with Corine LC data with a resolution of 100 m. This dataset allows one to directly identify the areas counting more than 100 people and fit the needed resolution. However, it must be noted that the population data provided by Euro-

stat for this model dates from 2001. Zonal statistics are extracted on this dataset as for the NDVI within the GIS software.

The next criterion addresses the quality of water in water bodies in the proximity of a waste facility. According to Stanley et al. (2011), the quality status of the water body must be known to address the question. If a water body is not of good (or better) status and is within 1 km of a waste facility then the reason for that status must also be checked. If the status is not good (or better) for reasons other than the mine then the status of the water body is deemed to be good (or better) and not due to the waste facility. As discussed in section 2.2.2, the quality of a water body cannot be related to one particular heap.

Natura 2000 sites are protected by legislation and regulations. The Natura 2000 Network is a network of important ecological sites across the European Union. A dataset with the same name localizes all these sites. This question seeks to know if a Natura 2000 site lies within 1 km of a waste facility. As mentioned in the introduction of this paper, the relevance of this criterion is severely discussed by Walloon authorities as well as biodiversity specialists.

Agriculture as used as the last criterion refers to both the growing of plants and the rearing of animals. Agricultural activities may be affected by pollution emanating from waste facilities and it is therefore important to determine if agricultural activity is practiced in the vicinity (Stanley et al. 2011). The Walloon dataset locating agricultural areas is the COSW (Carte d'Occupation du Sol de Wallonie - Walloon Land Cover Map) produced by the regional government.

3. Preliminary results

The 9 criteria seen at this stage as relevant in the Walloon test case are: (i) surface, (ii) height, (iii) slope, (iv) water course, (v) air, (vi) direct contact, (vii) population, (viii) nature, and (ix) agriculture. Their values for each of the 591 existing waste facilities are calculated and compared to thresholds provided by the guidance document. Tab. 2 presents for each criterion the percentage of waste facilities which overpass the thresholds.

Table 2. Selected heaps for each criteria.

Percent of heaps	
Surface	85.28%
Height	22.67%
Slope	14.89%
Water Course	1.35%
Air	22.50%
Direct Contact	22.50%
Population	98.14%
Natura	29.10%
Agriculture	100.00%

As discussed already, the Walloon region is densely populated and highly agricultural. A large majority of mining heaps are surrounded by nodes of more than 100 inhabitants or by crops and pasture lands

4. Next steps

It appears that the assessment of both Source and Receptor components of the level of risk need adaptation in order to make the protocol fully efficient at the Walloon regional scale. In their current forms, the surface, population and agriculture criteria lead to include 85 %, 98 % and 100 % of existing sites for further investigation, respectively. First, the current threshold value for the surface criteria is relatively arbitrary [1]. A thorough examination of the Walloon dataset needs to be performed in order to propose a more adequate value. Then, while the size of the populated cores is thought to be reasonable (100 inhabitants), a reflection on the size of the buffer (currently 1 km) needs to be initiated. Reducing this size, for example as a function of heap size and/or volume, would allow a more accurate assessment of the actual risks to humans. Finally, as for most of the cases chemical quality is not thought to be a critical feature of existing closed waste facilities at this initial step, ignoring agriculture as a potential receptor is also currently under consideration.

The assessment of the Pathway component of the level of risk seems relatively adequate in its current form. Risks associated to transmission by Air or Direct Contact lead to conclude that about 75 % of the heaps do no threaten human health or the environment. A possible mean for further reducing this ratio would be to take into consideration, where available, air quality measurements.

The thresholds identified as inadequate for the case of the Walloon Region will be discussed in the following weeks. In order to validate the removal of certain criteria from the protocol and the choice of new thresholds values, a series of sites were selected independently and will undergo a complete risk assessment. The sites were selected based on specific features, such as the type of material extracted, remaining available data, geographic position, … They are expected to be representative of the whole list of waste facilities in the Walloon Region. Field work, including waste, soil, groundwater and surface water sampling, and a thorough search for historical maps and mine documents will be conducted in order to accurately characterize the remaining risks for human health and the environment. The field protocol is under construction and being discussed with the authorities.

Once the modified protocol is validated, it will be applied in order to identify the sites needing deeper risk assessment. A second series of sites needing thorough investigations, involving field work as well, will be needed before a first version of the inventory can be finalized.

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