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METHOD OF SETTING LOCATIONS FOR MUNICIPAL SOLID WASTE COLLECTION POINTS IN PROTECTED AREAS

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Abstract

According to the amendment to the Act on maintaining cleanliness and order in communes, a stationary a municipal solid waste collection point (MSWCP) must be established in each Polish commune or commune union and situated close to the commune center. This point (MSWCP) should exist in the commune (or commune union), which are covered in 100% by protected zone. These objects are a new element in managing of the stream of municipal solid waste in Poland, known in the European countries as "household waste recycling centers" (HWRC).

The aim of the work was developing the procedure with the use of tools enabling setting potential locations for MSWCPs in protected areas. The developed method was applied (for verification of the assumptions) in the process of seeking optimal locations for MSWCPs in the communes located in the Świętokrzyski National Park (ŚNP) protection zone. The paper presents the methodology for setting locations for municipal solid waste collection points. A method was developed using the Analytic Hierarchy Process (AHP) and Geographical Information System (GIS).

It was possible to designate between 98 and 191 potential locations of MSWCPs in the communes situated in the ŚNP protection zone. The assumed criterion of maximum distance from the commune center eliminated 85% of locations. Optimal locations for MSWCPs in each commune were determined using AHP method. The main results of this research was to establish of MSWCP location for every commune in analyzed protected zone, based on the proposed methodology. The method presented in the paper may be a tool for the environment impact assessment of these investments.

Keywords: municipal solid waste, municipal solid waste collection point, GIS, AHP

INTRODUCTION

Both, the European Union and Polish regulations governing municipal solid waste management demand, that by 2020 the level of recycling wastes, such as paper, metal, plastics and glass or their preparation for re-use and recovery using other methods, would reach 50% in all member countries (Regulation 2012). On the other hand, the European Commission plans to reach 75% already by 2030 (CEP 2015). Establishing a municipal solid waste collection point (MSWCP) in each Polish commune may help to reach high levels of recycling. Investment plans concerning MSWCP setting in the Małopolska province comprise 48 objects of this type intended for extension or modernization, and construction of 199 new objects (Plan 2016a), while in the Świętokrzyskie province – 43 objects for extension or modernization and 32 new objects (Plan 2016b). According to the National Plan of Waste Management 2022 (KPGO 2022), there were 1871 municipal solid waste collection points operated in Poland in 2014, whereas the share of solid waste collected in the selective way was only 11.50% (KPGO 2022). The recycling level of waste collected in selective way in 2014 was 26%. In order to reach higher levels of recycling in the near future, it is necessary to set new MSWCP, i.e., places where the commune inhabitants will be able to bring, free of charge, their household waste, such as paper, metal, plastics, glass but also multi material packaging, used electronic and electric equipment, as well as construction and hazardous waste. These sites are intended to increase the volume of municipal solid waste, which may be then subjected to the processes of re-use, recycling or recovery. According to the amendment to the Act on maintaining cleanliness and order in communes, a stationary MSWCP must be established in each Polish commune or commune union and situated close to the commune center (Act 2015). MSWCP should be create in protected zones (while the whole area of commune is situated in protected zone), which should be excluded from locating in their area, new infrastructure of waste management.

Establishing a municipal solid waste collection point is the endeavor, which may potentially affect the environment. In result the entity planning MSWCP construction should conduct an environmental impact assessment of the construction, if such obligation was imposed (Act 2008). Currently, we lack the methodology, which would allow indicating the location of such objects. The usually selected localization is the area of existing sewage treatment plant or public utility company– the property of the commune. The advantage of these locations is constant presence of employees during the company working hours, junctions for the utilities, access or fence (Sadowski, Rydian 2016). These areas usually have the adequate infrastructure and monitoring system. Realization of the enterprise in the area of a sewage treatment plant or a company currently involved in waste management causes less complaints from the local dwellers (Sadowski, Rydian 2016). The disadvantage of locating these objects in such places is the fact that they are reluctantly visited by the local communities due to unpleasant smells. The optimal location is of key importance for the efficiency of the site operation. Designated far from human dwellings, with inconvenient access, these places will become only the obligation implemented by the commune. Unfortunately, the regulations in this respect are little precise (Terek 2013). Lack of such places in a commune leads to forming of illegal dumping sites (Malinowski *et al*. 2015).

The aim of the paper was developing and application (to verify the assumptions) of a method for setting potential locations for MSWCP in protected areas. The work covered the communes situated in the Świętokrzyski National Park protection zone. The use of GIS software and AHP method proved a basis for the developed method.

MATERIAL AND METHODS

Currently there are no precise and/or imposed guidelines concerning setting MSWCP locations, among others due to the fact that they are a new kind of municipal waste management objects in Poland. Some general guidelines for so called recycling centers, which are objects with a much wider scope of activities, appear in literature. However, only a description of the methodology for designing a similar environmental protection infrastructure, using special protection zones separating the designed object from various elements of the natural environment may be found in the literature of the subject (Zemanek *et al*. 2009; Castañeda 2014; Wota and Woźniak 2008; Gliniak and Sobczyk 2016). Using GIS tools and AHP method was developed in many scientific publications related to the search for the optimal location of waste management facilities (Moeinaddini *et al*. 2010; Şener *et al*. 2010; Wang *et al*. 2008).

The procedure of setting location for MSWCP using GIS tools and AHP method is presented below. The following boundary conditions were taken into consideration in order to develop an original method for designing MSWCPs:

- MSWCP should be located as close as possible to the commune center,
- the choice of location must be included in the local spatial management plan,

- the construction should be planned at a close distance from the local roads – the site must be easily accessible to transport means,
- the site should be planned in places where technical infrastructure equipment is already available or possible to install – due to economic reasons,
- it would be the best if the commune would be the owner of the plot.

The use of GIS – stage 1

The first stage of work involves setting potential MSWCP locations on digital maps of the area using Geographic Information Systems (GIS). Only one location criterion predisposing a given area for MSWCP construction was assumed in the paper. It is a 50 m wide strip of land on the right and left hand side of the road (100 m long strip of land along the most important hard-surfaced traffic route in the commune). Application of a 50 m wide buffer was suggested to minimize the costs of MSWCP construction, which would be involved in building the access roads and connecting to the technical infrastructure facilities. On the other hand, the areas useless for MSWCP location comprised:

- water intakes, flowing and stagnant waters + 50 m buffer zone,
- housing areas + 100 m buffer zone,
- socio-economic infrastructure facilities + 50 m buffer zone,
- green areas, forests, national parks, protected areas + 50 m buffer zone.

Individual elements of the natural environment constituting the useless areas were discussed in detail in the paper by Zemanek *et al*. (2009). The width of buffer zones was selected in result of the analysis of some MSWCPs already existing in Poland and located in protected areas or in their vicinity (among others in Krynica Zdrój, Muszyna, Szczawnica). The analysis revealed that the MSWCPs are places having a high acceptance rate among local communities and characterized by a low environmental impact. The boundaries of the lots where the existing and analyzed MSWCPs are situated are distant from:

- forests, green and protected areas, etc. between 33 and 65 m (on average 46 m),
- housing areas between 70 and 110 m (on average 88 m),
- flowing and stagnant waters, etc. between 22 and 78 m (on average 42 m),
- socio – economic facilities (concrete plant, cemetery, etc.) between 11 and 55 m (on average 30 m).

Experiences from the operation of the existing MSWCPs show that municipal waste mass, which may potentially be deposited in the designed MSWCPs in the analyzed communes, may be 5.8 ±2.0 Mg (from 1 to 3% of the waste mass collected in the commune). Therefore, the minimum area of municipal solid waste collection point should be 10 ares (Castañeda 2014). This area would ensure a free arrangement of containers with 1100-dm^3 volume and bigger (for example with 7 m^3 or 10 m^3 volume) for individual solid waste fractions, as well as construction of other facilities, such as a gatehouse, administrative building or hazardous waste storage facility.

According to the amendment of the act on maintaining cleanliness and order in communes, a MSWCP should be situated close to the commune center (Act 2015). Conducted simulations indicated that the distance should not be longer than 2 km.

For the purpose of the analysis (the method verification), digital thematic layers were obtained from the Świętokrzyskie Marshal's Office, illustrating individual elements of the natural environment and divided into the areas predisposed and not predisposed for the MSWCPs location. Merging and buffering of digital maps in ArcView GIS 10.2 software was done using Boolean algebra operations. Potential localizations of the objects (Fig.1) were created by cutting off the areas located on the thematic layers presenting the sum of excluded elements of the environment (together with respective buffer zones) from the predisposed areas layer. From the potential MSWCP locations (set in Arc View 10.2 GIS software) removed were all, whose area was smaller than10 ar. Only the locations situated within 2km from the commune center were taken into consideration at the second stage of the analysis.

The use of AHP method – stage 2

Analytic Hierarchy Process method was used in order to indicate the optimal MSWCP location (among the areas determined in GIS). So called reversible pairwise comparison conducted in the Analytic Hierarchy Process involves an assessment of objects among themselves and with respect to selected elements of the environment. The assessment results are put into quadratic pairwise comparison matrix. The matrix presents the assessments indicating the dominance of elements on its left over the elements at the top (Adamus and Łasak 2010). In the matrix, $n \cdot (n\text{-}1)/2$ pairwise comparisons are made. The number of comparisons results from the fact, that on the diagonal of the *n* element matrix, there are *n* ones, while a half of the opinions is inverses (Saaty 2008). The most important magnitudes, which are computed by means of the matrix of comparisons, are: λ_{max} (eigenvalue which is the comparison compatibility measure) and compatibility index (C.I.) representing the consistency in attribute comparison. A crucial element of AHP method is a 9-point scale of evaluation (Saaty 1980), where value 1 denotes equal importance of compared attributes or objects, whereas 9 denotes extreme difference (extreme dominance of one of the compared attributes over another). The scale is universal and finds numerous applications.

It allows to compare and evaluate quality factorswith quantity ones (Wota and Woźniak 2008).

The AHP method was first used for comparing the value of optimization criteria and determining weighted coefficients for individual optimization categories (Table1) and then for pointing out an optimal MSWCP location. The following evaluation criteria were assumed: geodesic area of the determined plot, which should be as big as possible, population density of the village where the designed area is situated (it should be as large as possible), distances from the commune center (as short as possible). The final criterion was the use of property intended in the spatial management plan. The most desirable was intended use of the plot for service providing facilities, then no spatial management plan for the given area, whereas the intended use of the plot in SMP for purposes other than service providing facilities was regarded as the least convenient. AHP procedure did not take into consideration the ownership right for the selected lots.

The Świętokrzyski National Park-verification of the developed method

Verification of the method was carried out in 7 communes where the Świętokrzyski National Park is situated. The area is a part of the Małopolska Upland called Świętokrzyski Land. Characteristics of analyzed area are shown in table 1. The Park occupies a small section of the Świętokrzyskie Mountains. Currently the park covers 7626.45 ha (www.parkinarodowe.edu.pl). Flora and fauna of the National Park is greatly diversified comprising c.a. 900 plant species, over 4000 invertebrate and 210 vertebrate species, as well over 100 bird species. Large animals encountered there are red deer (which is the symbol of the Park), wild boar, deer or moose.

Table 1. Characteristics of communities located in the buffer zone of the Świętokrzyski National Park

Municipality	Area [km^2]	Population	Population density [$persons \cdot km^{-2}$]	Area of arable land [%]	Forrest cover [%]
Łączna	62	5340	87	37	56.5
Bodzentyn	160	11697	73	50	45.3
Pawłów	137	15332	112	77	16.8
Nowa Słupia	86	9636	112	64	27.8
Bieliny	88	10171	115	65	30.1
Górno	83	13881	167	81,5	11.4
Masłów	86	10565	123	52	36.7

Source: www.kielce.stat.gov.pl

RESULTS

In result of cutting off the thematic layer of summed up unsuitable areas from the predestined areas, potential MSWCP locations were obtained, which were presented in Figure 1 and Table 2. The total number of obtained locations, the number of appointed areas of more than 10ares and the number of potential locations situated at the distance of 2 km from the commune center was compiled in Table 2. The number of locations designated in individual communes was determined by the Świętokrzyski National Park area proportion in the commune area and the percentage of agricultural lands with low soil quality class. The average number of designated areas predisposed for MSWCP location in the analyzed communes was 142. After elimination of the areas of less than 10ares, on average 108 such places were left. The criterion of the distance from the commune center (regarded as the commune authorities headquarters) caused a decrease in the number of potential MSWCP locations on average by 85%. In this way the highest number of locations was eliminated in the Pawłów commune and the fewest in the Łączna commune. The locations set within the 2-km buffer zone from the commune center were illustrated in Figures 2a-2f.

Because no optimal MSWCP locations were indicated in result of analyses using GIS system, it was necessary to use AHP method. Table 3 presents the results of pairwise comparison of the assessment criteria – values of weights for the analyzed criteria. The estimated value of the compatibility index was: CI = 0.098. The distance from the commune center (0.57) proved most important criterion according to the expert assessment made by the representatives of commune office, whereas the plot area was the least important (0.04).

Table 2. Number of designated areas predisposed to MSWCP location

Commune	Łączna	Bodzentyn	Pawłów	Masłów	Górno	Bieliny	Nowa Słupia
Number of designated areas	98	127	191	191	153	115	124
Number of designated areas over 10 ares	65	83	149	132	119	103	107
Number of potential locations 2 km from the commune center	30	21	11	18	24	20	18

Source: Own study

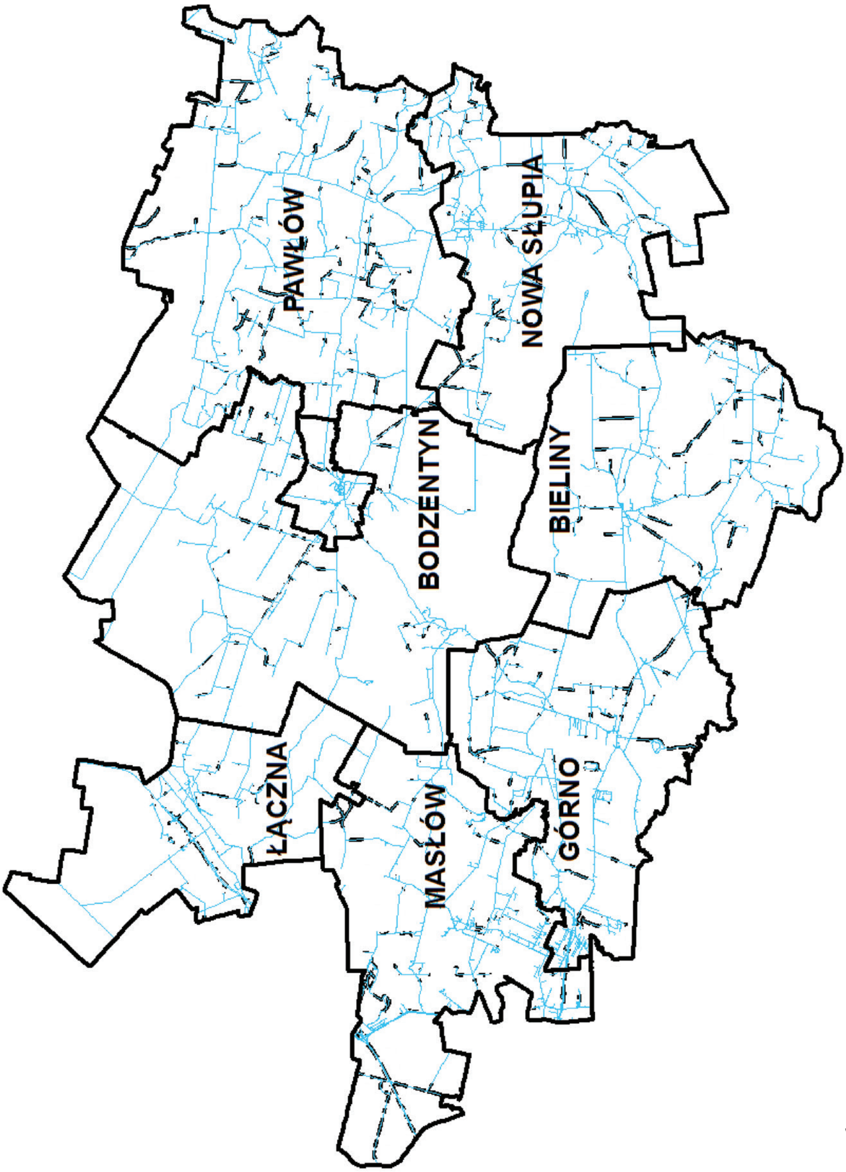
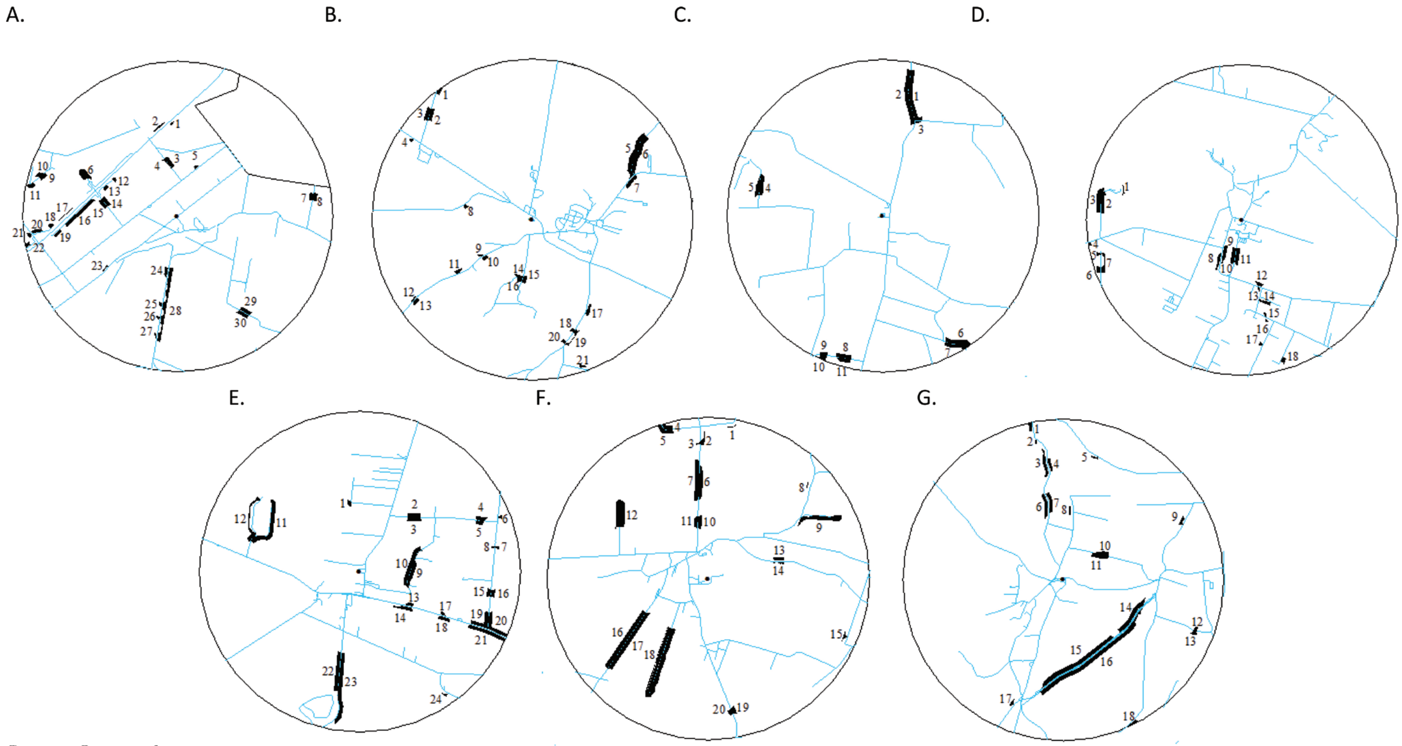


Figure 1. Location of potential MSWCPs

Source: Own study



Source: Own study

Figure 2. Location of potential MSWCPs. A – Łączna commune, B – Bodzentyn commune, C – Pawłów commune, D – Masłów commune, E – Górno commune, F – Bieliny commune, G – Nowa Słupia commune

Table 3. The assessment criteria (results of criteria comparison in AHP method)

No.	Criterion	Weight of criterion
1	Plot area	**0.041**
2	Intended use in LSDP	**0.275**
3	Distance from commune centre	**0.570**
4	Population density	**0.114**

Source: Own study

The use of AHP method allowed for arrangement of the designated locations according to the assumed criteria and indicating the optimal location.

On the basis of assumed optimization criteria, the best (optimal) locations for the establishing the municipal solid waste collection points were selected in each of the analyzed communes. The optimal areas for the localization of municipal solid waste collection points are the following: in Łączna commune – area no. 3, in Bodzentyn commune – area no. 8, in Pawłów commune – area no.3, in Masłów commune – area no. 11, in Górno commune – area no. 10, in Bieliny commune – area no. 10 and in Nowa Słupia commune – area no. 14.

The area set as optimal in Bodzentyn commune has been also indicated by the Commune Office in the independent analysis for the construction of the first MSWCP in this region.

CONCLUSION

Despite the fact that the analyzed area is located in the protection zone of the National Park, it was possible to designate potential MSWCP locations using GIS software, with selecting the predisposed area as a 100 m wide buffer zone along the hard-surfaced roads and indicating the optimal location by means of AHP method. The presented method may be also applied for designing MSWCP locations in other communes and provide help in developing the environmental impact assessment.

Verification of the method carried out in 7 communes situated in the protection zone of ŚNP allowed to designate from 98 to 191 potential areas for MSWCP locations, among which on average 15% provides a quasi-optimal solution.

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