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**Quantitative assessment of household  
waste disposed in floodplains of rivers  
from extra-Carpathian region of Neamț  
county, Romania**

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### **ABSTRACT**

This paper aims to develop a method which estimates the amounts of household waste disposed (HWD) by rural localities in floodplains of rivers from subcarpathian sector ( Bistrița, Cracău, Ozana) and also from corridor valleys sector of Moldova and Siret rivers. This approach takes into the consideration the average distance between the outer limits of built-up area (village) and floodplain (river) in order to calculate the specific indicators. This method is applied for 2003 and 2010 with a view to highlight the potential impact of illegal dumping on rivers sectors from extra-Carpathian region between pre-accession and post-accession periods. Poor waste management facilities from rural areas lead to this bad practice which prevailed during 2003-2009. Recent improvements in this sector, particularly after the closure of rural dumpsites (16 July 2009) will mitigate this environmental threat which it is also specific to others rural regions from Romania.

**Keywords:** household waste, uncontrolled disposal, floodplain, rural areas

### **INTRODUCTION**

Recent studies shows that rural waste management sector has become a great challenge for Romania in order to comply the EU regulations at regional and local scale [1],[2],[3]. Low coverage rate of waste collection services (WCS) from rural areas in the last years led to improper waste disposal threatening the local environment [4],[5]. Frequently, mountain streams and floodplains or rivers from subcarpathian sector are most exposed to the illegal waste disposal [5],[6]. Waste dumping is still a major pollution source in rural environment and quantitative assessments are needed to be developed. This paper proposes a such method in a geographical context, for a more proper analysis of this environmental issue from rural areas.

### **METHODS**

The paper performs a quantitative analysis of household waste disposed (HWD) in floodplains of rivers from subcarpathian depressions (Ozana, Bistrița, Cracău) and corridor valleys sector of Moldova and Siret rivers across the Neamț county.

The starting point is the  $Q_{ud}$  indicator – estimated amounts of household waste uncontrolled disposed which is calculating after methodology developed by [5] :

- $Q_{ud} \text{ t/yr} = Q_{wu} - Q_{rh}$ ,  $Q_{rh}$  - potential reuse and recovery of waste in individual households,  $Q_{rh} = 0.7 * Q_{bw} + 0.1 * Q_r$ ,  $Q_{bw}$  - biodegradable fraction,  $Q_r$  - recyclables, data for these fractions are extracted from values of  $Q_{wu}$  using waste composition in Neamt County [7].
- $Q_{wu}$  amounts of household waste uncollected,  $Q_{wu}(\text{t/yr}) = P_u * I_g * 365 / 1000$ ,  $P_u$  – nr. of inhab. unserved by WCS,  $I_g$  – average per capita waste generation rate,

The main difference is that  $Q_{ud}$  indicator is calculating at village scale (most detailed) even for those localities which are covered by WCS. In these cases, the  $Q_{wu}$  indicator is calculated taking into account the collection efficiency established at 30 % in 2003, and 60 % in 2010 [6]. This paper correlate the collection efficiency ( $C_{ef}$ ) to the age of WCS ( $A_{WCS}$ ) from a commune in following scenarios:

- $C_{ef} = 60 \%$ , if  $A_{WCS}$  is 1-2 years, most cases in county
- $C_{ef} = 80 \%$ , if  $A_{WCS}$  is 3 years (Gherăești, Sagna & Săbăoani communes)
- $C_{ef} = 90 \%$ , if  $A_{WCS}$  is 4 years (Cordon)
- $C_{ef} = 100 \%$ , if  $A_{WCS}$  is > 4 years (Trifești)

Population census from 2002 is the source of demographic data at village scale because the data from the new population census of 2011 are not yet available (final results). Thus, the  $Q_{wu}$  is calculated in 2003 and 2010 according to  $C_{ef}$  as follows:

- $Q_{wu2003} \text{ t/yr} = P_t * I_g * 365 / 1000 * C_{ef}(0,3)$ ,  $P_t$  – total population of village
- $Q_{wu2003} \text{ t/yr} = P_u * I_g * 365 / 1000$ ,  $P_u$  - nr. of inhab. unserved,  $WCS < 60 \%$
- $Q_{wu2010} \text{ t/yr} = P_t * I_g * 365 / 1000 * C_{ef}$ ,  $WCS > 60 \%$ , depending of  $A_{WCS}$

These adjustments of  $Q_{wu}$  are necessary in order to calculate the  $Q_{ud}$  indicator for all localities from study area, even they are or not connected to WCS. Also, these improvements allow a more accurate analysis at local scale. The next step is the calculation of  $Q_{df}$  indicator (amounts of HWD in floodplains) based on the average distance between a village (outer limit of built-up area) to the river floodplain in the proximity, using following formula:  $Q_{df} = Q_{ud}(\text{t/yr}) * S_{ad}$ ,  $S_{ad}$  – weighted of  $Q_{ud}$  based on the average distance according to the table 1.

Tab.1 Correlation between  $Q_{ud}$  and average distance ( $A_d$ )

Average distance between outer limit of built-up area (village) and limit of floodplain	The weighting of $Q_{ud}$
1500 -1200 (m)	0.2
1199-900	0.4
899-600	0.6
599-300	0.8
299-1	0.9

Floodplains exposed to illegal dumping of waste are those located in the proximity of a locality (average distance <1.5 km).

The gap (300m) and amplitude (0 to 1.5 km) are larger than the average distance in mountainous region [6] because there are more compact settlements in the absence of natural barriers and the waste can be easily transported (from anywhere in the the village) and discharged into wider floodplains from Subcarpathian sector such as Ozana river (including Nemțisor tributary) Cracău, Bistrița and also into the larger floodplains of Moldova and Siret rivers. The distance is calculated at least in 5 reference points ( even more if morphology of village imposes) following the line of last households compared to the outer limit of floodplains in the proximity. These distances are measured using satellite images from GoogleEarth as an easy and accessible tool (fig.1). Then, it performs an arithmetic mean of these reference points, the gap of 300 m between classes limits the potential errors in the measurement process.

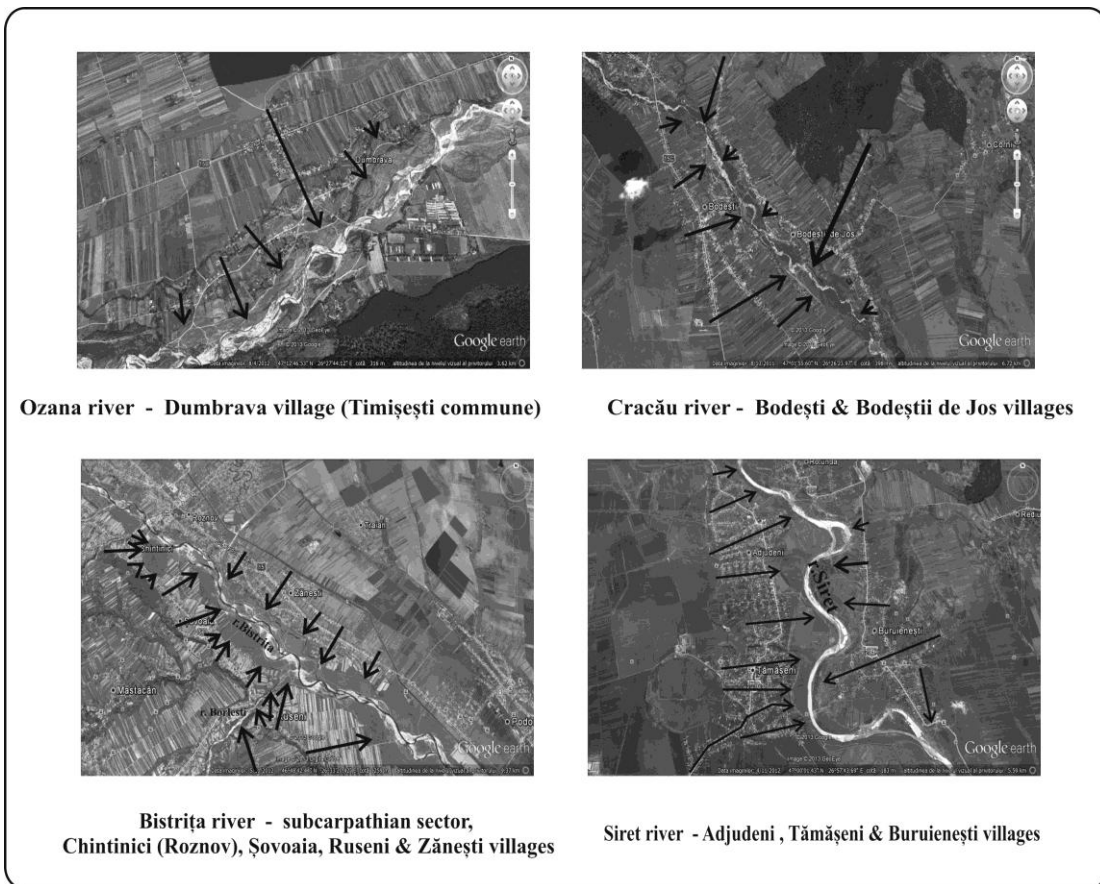


Fig. 1 Measurement points for calculating the average distance between built-up area (line of last households) and floodplains in the proximity using GoogleEarth images

This method is complementary to that analyzed in the mountain region [5] because of different geographical context. Both methods are based on the same principle of "proximity and convenience" which prevails in rural communities behavior (those where lacking waste collection services or where these services are poor or recently implemented) regarding the uncontrolled waste disposal problem.  $Q_{df}$  indicator is applied for 2003 and 2010, aiming to compare the potential impact of HWD in floodplains in the proximity of built-up areas. Waste management issue must be linked to geographical conditions [8].

## RESULTS AND DISCUSSION

This analysis takes into account on the one hand the pre-accession period (2003-2006) when rural waste management facilities were lacking or rudimentary and on the other hand, the post-accession period (2007-2010) when WCS were developed especially after the closure of dumpsites (16 July 2009) but nevertheless the coverage rate of WCS for rural population is still below the Romanian average and also for North-East Region. The average distance values ( $A_d$ ) on  $Q_{ud}$ ,  $P_{ad}$  and  $Q_{df}$  for 2003 and 2010 are presented in two tables (Tab. 2 & Tab.3) that share the Subcarpathian sector (Ozana, Cracău, Bistrița) and corridor valley sector (Siret and Moldova rivers) across selected localities in the vicinity of floodplains.

Tab.2 Values of the indicators applied for localities from subcarpathian sector

Village / River (total)	$A_d$ (km)	$S_{ad}$	$Q_{ud}2003$	$Q_{df}2003$	$Q_{ud}2010$	$Q_{df}2010$
Nemțisor	0,74	0,6	67,65	40,59	40,73	24,438
Lunca	0,614	0,6	53,3	31,98	32,1	19,26
Vânători-Sat	0,768	0,6	220,47	132,282	132,75	79,65
Blebea	0,31	0,8	43,542	34,8336	18,35	14,68
Dumbrava	0,483	0,8	70,39	56,312	29,67	23,736
Plăieșu	1,181	0,4	47,523	19,0092	20,03	8,012
Timișești	0,61	0,8	76,33	61,064	32,173	25,7384
<b>Ozana ( &amp; Nemțisor)</b>			<b>579,205</b>	<b>376,0708</b>	<b>305,803</b>	<b>195,5144</b>
Oșlobeni	0,704	0,6	60,473	36,2838	25,48	15,288
Bodești	0,904	0,4	128,72	51,488	54,25	21,7
Bodeștii de Jos	0,77	0,6	105,79	63,474	44,59	26,754
Versești	0,7	0,6	13,514	8,1084	20,34	12,204
Căciulești	0,9	0,4	26,197	10,4788	39,43	15,772
Girov	0,84	0,6	64,91	38,946	97,7	58,62
Botești	0,642	0,6	29,88	17,928	37,43	22,458
Doina	0,32	0,8	24,866	19,8928	18,9	15,12
Dănești	0,66	0,6	13,8	8,28	20,59	12,354
Slobozia	0,59	0,8	183,26	146,608	193,1	154,48
<b>Cracău (total)</b>			<b>651,41</b>	<b>401,4878</b>	<b>427,49</b>	<b>354,75</b>
CUT	0,844	0,6	102,45	61,47	19,7	11,82
Brășăuți	0,414	0,8	32,72	26,176	62	49,6
Săvinești	0,726	0,6	234	140,4	141	84,6
Zănești	0,764	0,6	297,73	178,638	313,74	188,244
Chintinici	0,402	0,8	58,69	46,952	61,84	49,472
Șovoiaia	0,732	0,6	34,75	20,85	36,61	21,966
Ruseni	0,99	0,4	212,24	84,896	223,66	89,464
Frunzeni	0,418	0,8	39,85	31,88	16,8	13,44
<b>Bistrița (total)</b>			<b>1012,43</b>	<b>992,7498</b>	<b>875,35</b>	<b>508,606</b>

The more permissive and favorable geographical context favors the construction of households resulting a compact morphology of villages which occupy larger areas on river terraces than mountain region. Therefore, the distance between the outer limits of built-up area and floodplain of river exceed 0.5 km with some exceptions such as (Blebea, Dumbrava , Frunzeni) when  $S_{ad}$  value is 0.8 in these cases.  $Q_{ud}$  values varies depending on demographic factors and on the other hand, due to the presence of WCS. In 2003, these services covered some communes near the urban areas such as Vânători Neamt, Dumbrava Rosie, Girov and Săvinești communes but nevertheless the uncontrolled waste disposal was widespread. This bad practice was tolerated by local authorities and because of that, the  $C_{ef}$  is considered to be only 30 %. Differences existing between the years 2003 and 2010 at the village level is due to extension of WCS in most localities except those included in the administrative area of cities such as Tg. Neamț (Blebea) and Roznov (Chintinici & Slobozia villages) where illegal dumping on floodplains still prevails. The tributary of Ozana river, respectively Nemțisor is passing near the village (namesake) and Lunca which is located between the floodplains of these two rivers (reflected by village toponym Lunca – or ‘‘Floodplain’’ into english) near the confluence area, these sector being vulnerable to uncontrolled disposal of waste. In this context, the relatively low distance ( $A_d$ ) between these two outer limits of floodplains (which include the built-up area of Lunca village) promote this bad practice in both sides. Field observations from September 2009 revealed that all localities considered disposed the household waste into floodplain of Ozana river. Furthermore, villages included in Girov commune (Girov, Verșești, Căciulești, Botesti, Doina, Dănești) who did not receive such services in 2010 led to an increase of  $Q_{df}$  (354 t/yr) indicator for Cracău floodplain, although overall value is lower than in 2003 (401 t/yr), because the existing of WCS in Bodești commune.



Fig. Rural dumpsites on Bistrița and Cracău floodplains from subcarpathian sector

Densely populated subcarpathian sector of Bistrița river which include a large alluvial plain downstream of Piatra Neamț city (also exposed to stronger floods, used as pasture for various livestock) it is a favorable site for improper waste disposal along the rural communities in the proximity. Compared to other rivers, this impact is most obvious,  $Q_{df}$  values being at least twice as large in 2003 (992.72 t) compared Cracău (401.48 t) or Ozana (376 t) although there are some waste collection facilities in villages of Dumbrava Roșie and Săvinești communes. In the latter case, it was operational a non-hazardous industrial landfill which served Săvinești industrial platform and also a partial population of homonymous commune. The same hierarchy is kept for 2010 (508.6 / 354,7/ 195,5 t/yr) but the potential impact is reduced due to lower values of  $Q_{df}$ . Illegal dumping is still an environmental threat as confirmed by field observations. Localities pressure on floodplains in the proximity it is significant taking into account the high values of  $Q_{df}$  indicator particularly in 2003. In some cases, the values are over 100 t/yr (Slobozia, Vânători-Neamț, Săvinești, Zănești) between 50-100 t/yr (Dumbrava, Bodești, Bodeștii de Jos, Cut & Ruseni villages) and others frequently over 20 t/yr. As regard 2010, the most of these values decreased but some localities has a higher impact of illegal dumping such as Zănești (188 t/yr), Ruseni (89,4 t/yr) in the proximity of Bistrița river or Slobozia (154 t/yr) near the Cracău river. Some values decreased but nevertheless they reflect a threatening to rivers such as Vânători-Sat (79 t/yr) and Girov (58 t/yr). Floodplains of Moldova and Siret rivers are also susceptible to uncontrolled waste disposal as shown in Tab. 3.

Tab. 3 Values of the indicators applied for localities from corridor valley sector

Village / River (total)	$A_d$ (km)	$S_{ad}$	$Q_{ud}2003$	$Q_{df}2003$	$Q_{ud}2010$	$Q_{df}2010$
Soimărești	0,818	0,6	23,167	13,9002	9,76	5,856
Preuțești	0,736	0,6	35,4	21,24	14,92	8,952
Zvorănești	0,724	0,6	9,86	5,916	4,15	2,49
Lunca Moldovei	0,966	0,4	20,197	8,0788	21,28	8,512
Tupilați	1,038	0,4	116	46,4	48,9	19,56
Munteni	0,364	0,8	23,64	18,912	24,91	19,928
Roșiori	0,342	0,8	17,93	14,344	18,9	15,12
Simionești	0,762	0,6	51,206	30,7236	5,39	3,234
Cordun	0,96	0,4	146,72	58,688	15,46	6,184
Horia	1,078	0,4	226,62	90,648	95,52	38,208
Cotu Vameș	0,838	0,6	195,37	117,222	82,35	49,41
<b>Moldova (total)</b>			<b>866,11</b>	<b>426,0726</b>	<b>341,54</b>	<b>177,454</b>
Rotunda	0,914	0,4	99,44	39,776	104,78	41,912
Buruieniști	0,69	0,6	219,19	131,514	230,98	138,588
Adjudeni	0,86	0,6	264,24	158,544	278,49	167,094
Tămășeni	1,012	0,4	226,56	90,624	238,74	95,496
Lutca	0,696	0,6	27,86	16,716	11,74	7,044
Recea	0,62	0,6	44,731	26,8386	18,854	11,3124
Spiridonesti	0,776	0,6	16,276	9,7656	17,15	10,29
<b>Siret (total)</b>			<b>898,297</b>	<b>473,7782</b>	<b>900,734</b>	<b>471,7364</b>

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This impact was significant in 2003 when WCS were absent, reflecting high values of  $Q_{df}$  indicator ( $> 50$  t) for some well populated localities in the vicinity of rivers such as Cordun, Horia, Tămășeni or very high ( $> 100$  t) for localities Cotu Vameș, Buruienești and Adjudei. In the last two cases, the  $Q_{df}$  indicator values are higher than in 2003 because in this period of time Doljești and Tămășeni villages were not covered by WCS. Almost the same situation was for Moldova and Siret valleys regarding the  $Q_{df}$  values (over 400 tons), major disparities between 2003 vs 2010 (426/177,4 t/yr) is explained by the development of WCS in Cordun, Drăgănești, Timișești and Tupilați villages. Only small villages and low population such as Roșiori and Munteni (Dulcești commune) were unserved by WCS but their impact is lower ( $< 20$  t./yr).

Floodplain of Siret was significantly susceptible to uncontrolled waste disposal in all period (2003-2010) due to lack of waste disposal facilities which were present only in two less populated villages such as Lutca as part of Sagna commune and Recea from Ion Creangă commune. Values of  $Q_{df}$  indicator for 2003 and 2010 are relatively constant (473.77/471.73 t/yr) reflecting the lack of overall investments in waste management sector from this region. Development of WCS is emerging after the closure of rural dumpsites in 2009 [9]. The same relative impact of HWD in floodplains is for Cracău, Siret & Moldova rivers in 2003 (over 400 t/yr). The most exposed to illegal dumping for both years was Bistrița river and less exposed was Ozana river. Significant decrease of  $Q_{df}$  (2003 vs 2010) was estimated for floodplain of Moldova river (426/ 177.4 t/yr). This indicator shows first quantitative data concerning the illegal dumping of waste on river floodplains from Romania located in extra-Carpathian region. These estimations suggest that localities in the proximity of these rivers disposed almost 2670 t of household waste in 2003 and 1708 t in 2010. The values reflects serious environmental issues related to a rudimentary waste management in rural areas. Traditional waste management system encourage these bad practices of rural communities. The new integrated waste management system (which is under implementation) represents the main expentency in improving the current situation. However, rural waste management is still far from EU obojectives. The extensions of WCS in rural communities is only the first step in combating the illegal dumping. A proper waste management infrastructure is nedeed but also the local communities must be resposanble in this matter.

## CONCLUSIONS

Every village from study area exert a certain pressure on floodplains of rivers by waste dumping. Field observations from study area confirmed this bad practice across all localities. Development of WCS mitigate the problem of illegal dumping but this environmental threat is still present particularly along the localities from Siret valley and subcarpathian sector of Bistrița river. These improper sites are vulnerable to stronger floods which became more frequently after 2003. The waste disposed are transported, thus, increasing the destructive power of this natural hazards in downstream. The method proposed in this paper continues the quantitative assessment methods of illegal dumping apllied at local administrative territorial units [5] or for mountain rivers [6]. These methods are necessary tools for EIA studies concernig the rural waste management issue.



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