WASTE MISMANAGEMENT IN DEVELOPING COUNTRIES: A CASE STUDY OF ENVIRONMENTAL CONTAMINATION

Navarro FERRONATO[1], Vincenzo TORRETTA[2], Marco RAGAZZI [3], Elena Cristina RADA[4]

Solid waste management in developing countries represents a dangerous issue due to environmental impacts and human illnesses triggered by waste releases in water bodies and by the practice of the open burning, which are mostly underestimated by the Governments. Lack of economic funding, public awareness, technological facilities and know how worsens the situation, giving low hopes of improvement. In this paper, a field work implemented within a Bolivian city is proposed, giving an example of current solid waste management activity in a low-middle income country, highlighting environmental and social issues. A few estimations about environmental impacts are presented while some suggestions are provided.

Keywords: Developing countries, Solid Waste Management, Environmental impacts.

1. Introduction

Waste collection, processing and final disposal still represent a problem in many low-middle income regions [1-3]. This is due to waste management multifactorial issues which involved technical, environmental, financial, socio-cultural, institutional, legal frameworks and tourism, which are not fully considered in such emerging countries [4-9]. As a result, where public awareness and municipal solid waste (MSW) services miss, people burry or burn their own waste or an informal recycling sector start to operate within the area, like only feasible activity for poor households for receiving an income [10-12]. The recycling rate

[1] PhD student, Department of Theoretical and Applied Sciences, University of Insubria, Italy; email: nferronato@uninsubria.it
[2] Prof. Eng., Department of Theoretical and Applied Sciences, University of Insubria, Italy; email : vincenzo.torretta@uninsubria.it
[3] Prof. Eng., Civil Environmental and Mechanical Engineering Department, University of Trento, Italy, e-mail: marco.ragazzi@unitn.it
[4] Dr. Eng., Civil Environmental and Mechanical Engineering Department, University of Trento, Italy & Department of Theoretical and Applied Sciences, University of Insubria, Italy; e-mail: elena.rada@unitn.it

achieved by the informal sector in developing countries is quite high, often in the range of 20-50%, comparable with those achieved by modern waste management systems [6,13]. However, since informal waste collection, recycling and disposal are low paid activities, workers are often not aware of labour related risks and they generally do not have access to adequate medical treatment [14-16]. Awareness of waste management practices could be developed with experiences and understanding of environmental issues within the municipalities starting from sensitive campaigns at school and by integrated Law and regulations applied by local Governments. Moreover, stakeholders cooperation, Universities inclusion and international agreements, among all partners, can allow improving solid waste management practices rapidly and in a sustainable manner [17-19]. Changing the knowledge from 'waste to disposal' to 'waste as a resource' is a sustainable way for decreasing environmental impacts due to waste mismanagement. Waste to recovery and waste to energy is a new common practice in developed countries, although energy recovery is a second order form of waste exploitation. Indeed, the priority should be given to material recycling and reduction, which are closely related to waste and environmental impacts minimization. Thus, also low-income countries should introduce this practice [20-25].

The present paper introduces the above management issues in a South American low-middle income country where environmental impacts and lack of resources is a challenge which must be overcome. Bolivia is the country proposed, giving particular emphasis to a small city of 30,000 inhabitants, where the environmental impacts are not considered by the population and by the municipality. An overview of the region is introduced, highlighting environmental issues and socio-cultural characteristic of the city, while suggestions for future improvements are provided. This study represents and original contribution since evaluates the environmental pollution in a low income reality, assessing the quantity of leachate and gas released by the local dump site, the social equity and providing suggestions for improving the MSW management for a developing region.

2. Strategies implementation

The study has been carry out by a direct collaboration with the municipality of Monteagudo, a small city within the department of Hernando Siles in the Chuquisaca region. The survey comprehend a field work of 10 days together with interviews to the local engineers and to the components of the environmental secretary, visits to the dump site and a questionnaire survey applied to a group of young students which lived in the city. In order to better understand the context where the survey took place, a brief description of the city is provided below.

Monteagudo is located within the Chuquisaca region, 315 km far from Bolivian capital city, Sucre, and at an altitude of 1,250 above the sea level. The city covers an area of 1,439 km^2 and the households live mostly within the city centre (73%), with a population density of 14.29 inhabitants per km^2, while the others live and work within the country. Monteagudo is situated in a Sub-Andean mountain region, characterized by high variations of temperature and low meteoric precipitation, about 923 mm per year. The citizens live mostly of agriculture, breeding and petrol extraction as is the most important industrial activity spread in Bolivia.

3. Results

The survey conducted in Monteagudo allowed studying issues related to the MSW management activities, evaluating technical capabilities, the presence of the informal sector, the recycling systems, the releases of the open dump site and the social behaviour.

3.1. Solid waste collection and generation

Solid waste management is implemented by the Municipal Government of Monteagudo, which directly control and manage the collection and the final disposal. Street sweeping is applied manually during the collection service, like the gathering of the hospital waste and markets refuses, which happen daily and without any different treatment. The means used for the collections are one compactor track, an open track and few carts, the latter used for street sweeping. Solid waste collection covered 80% of the city area, giving more preference to the city centre. All users give the waste directly to the transport means, as households are advised by a sound alert during service transition. However, the streets are mostly dirty and with high amounts of garbage scattered, where animals and flies are usually present. Collection routes are not planned and depends on streets dirty. The service applied is paid only for the 30% by the citizens, as public charges are not sufficient to cover all service cost. As a result, Bolivian Government finance such operations, without the possibility to implement new technological improvements.

Within the city there are not many sensitivity campaigns; every month the population clean parks, public spaces and roads, as in 2011 were introduced the '*day of the solid waste'*, where all households are invited to maintain the cleanness of the city. Solid waste dump is forbidden within water bodies and open spaces, however, uncontrolled dumping is common within the area. Moreover, open burning is widespread in the city, since solid waste are commonly burned outside the houses.

The last study implemented within the city estimated that the production of MSW within the city is about 0.39 kg/inh. per day with an average density of 271 kg/m^3 [26]. Waste fractions are reported in Table 1.

It is visible how the inert fraction (construction waste) is significantly present within waste composition, as is direct consequence of the considerable urban expansion and building construction within the city. However, excluding this fraction, is evident the percentage of organic matter typical of developing countries, as reported in other studies worldwide [27-29].

Table 1

***Monteagudo* waste composition**

Material	Fraction (%)
Organic matter	49
Plastic	7.24
Paper and cardboard	2.49
Metal	1.27
Glass	0.37
Hazardous waste	0.29
Inert	31.19
Other	10.3

As a result, every day within the city 11 tons of MSW are produced for an annual contribution of 4,125 tons, if summed with the solid waste generated by the markets. All this material is finally disposed in an open dump site without any precaution.

3.2. Informal sector and final disposal

The waste produced in Monteagudo is disposed to an open dump site without formal recovery or pre-treatment, as typically happen within the majority of developing countries [30-32]. The open dump is located 3 km far from the city centre, it covers an area of about 0.5 ha and it was built in 2011. The previous final disposal site was located nearest the city, and has been closed for odours and general impacts which affected the citizens. The current site is near a valley, where residual waste are stored without any technical precaution required for the protection of the environment such as daily covering, waterproofed base, natural gas burning, leachate caption and treatment. Every typology of waste is stored here, and comprehend hazardous materials, hospital waste and slaughterhouse remains, enhancing the impacts which the environment is subjected [33].

Within this partially controlled area, informal recycling activities took place, as depicted in Figure 1. Women are used to gather exploitable materials, like plastic or metals, which are sold to the recycling industry located in Santa Cruz. Indeed, every two weeks, open trucks come to Monteagudo to collect and buy recyclable materials, applying an effective informal regional reverse logistic system.

Generally, 1.8 tons of plastic are gathered every two weeks. However, this activity is dangerous for the people who works in, as are in contact with hazardous materials, sharp residual materials, dangerous liquids and flies, vectors of illnesses such as *dengue* and malaria.

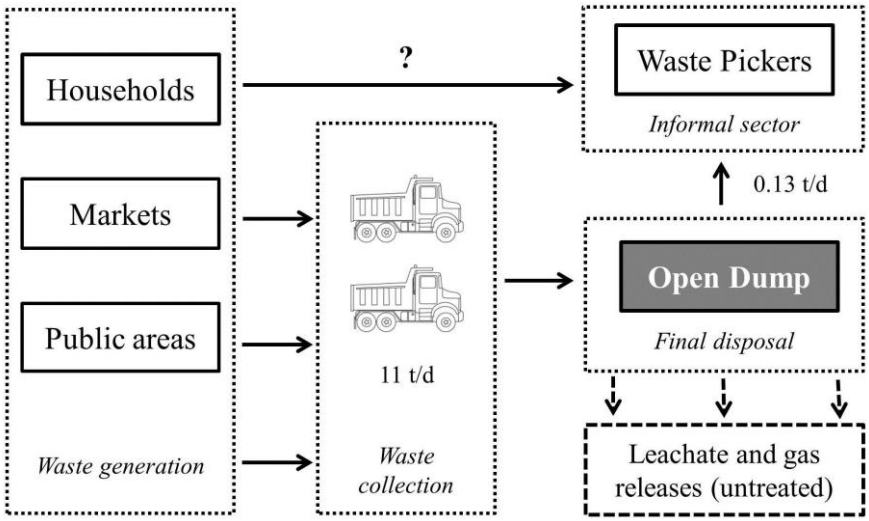

Fig. 1. General scheme of MSW generation, collection and disposal in Monteagudo

3.3. Assessment of the leachate and the landfill gas released by the open dump site

For evaluating the environmental impacts due to the mismanagement of the open dump site, we estimated the quantities of landfill gas and leachate produced during the years after the starting operation of the site. To do so, some simplifications were introduced in terms of amounts of waste disposed, temperature, rain and area of the site. Indeed this information are not supported by reliable data.

For the estimation of the landfill gas released, we adopted the method *LandGEM*, provided by the American environmental protection agency (EPA). It considers the variation by the time of the landfill gas produced by the computation of the following equation [34]:

$$Q_{CH4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} k \cdot L_0 \cdot \left(\frac{M_i}{10}\right) \cdot e^{-kt_{ij}} \quad (1)$$

Where Q_{CH4} is the annual production of methane, i is the index which considered the annual increase of waste, n is the year of the calculation, j is the increase of the

calculation into each year, *k* is the constant related to the kinetic of methane production (considered equal to 0.05), L_0 is the capacity of methane production (170 m^3/t of waste), M_i is the quantity of waste disposed in the year *i*, while t_{ij} is the age of the quantity disposed in the year *ij* [34]. In particular, the model estimates the quantity of methane, non-methane organic compounds (NMOC) and carbon dioxide. The most dangerous contaminant produced by the dump site is methane, since its green-house effect is 24 times higher than carbon dioxide.
The general hypothesis made for the calculation are the following:

- the quantity of waste disposed from the year 2011 is about 24,090 tons (the half composed of putrescible fractions);
- the 50% of the landfill gas produced is methane;
- the open dump site is considered as a controlled landfill;
- the mass of methane and dioxide carbon increase linearly.

By the equation (1), it can be estimated that in six years the methane produced is equal to 431.34 tons, about 645,500 Nm^3 (density equal to 0.667 kg/m^3), while the CO_2 produced is about 1,183.49 tons (1.831 kg/m^3), which will increase during the next years since the open dump site is still in operation (Figure 2). It means that, in six years, the open dump site alone contributed to the Green-House gas (GHG) emission as about 9,000 cars which travels 10,000 km per year and which produce 127 gCO_2/km. This quantity of GHG produced represent the cumulate quantity generated during the years, without considering variation of the seasonal conditions, waste fractions and generation per inhabitant. However, it provides an useful data for estimating the main impact due to waste mismanagement.

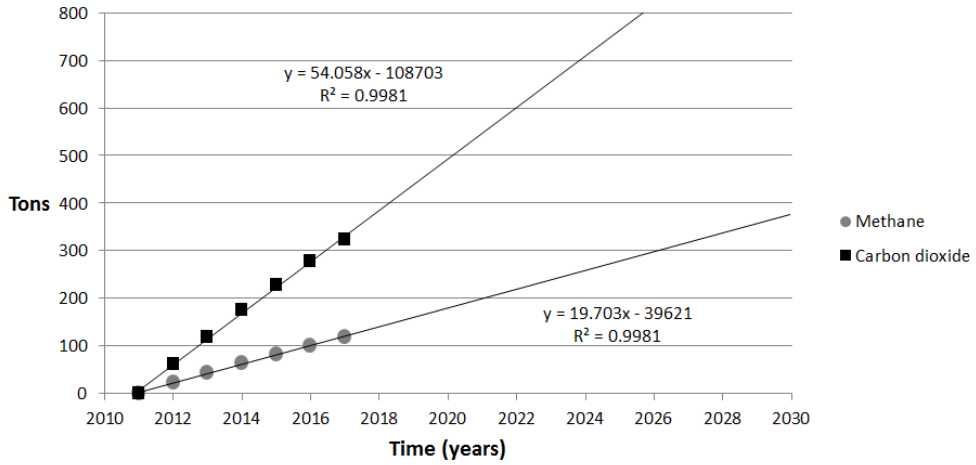

Fig. 2. Tons of methane and carbon dioxide released during the years by the open dump site according to the results of equation (1).

For estimating the production of landfill leachate (LL), it has been considered that the annual precipitation during an ordinary year is about 923 mm and that the area of the disposal site is about 0.5 ha. The equation considered is the following:

$$Q_{LL} = 0.3 \cdot P \cdot A \cdot \left(\frac{1}{1000}\right) \quad (2)$$

Where Q_{LL} is the flow of leachate measured in m^3 per year, 0.3 is the coefficient which take into account the variation of the infiltration of the rain into the soil while *A* is the area of the open dump site. The equation provides a stream of about 1500 m^3 of leachate per year, with high concentration of COD, BOD, N, P, and heavy metals, among others pollutants [33]. As mentioned above, the quantity does not considered the seasonal variation of the leachate release and it represents an average which could allow decision makers to introduce measures of mitigation for preventing environmental contamination and improving the health of the local population.

In conclusion, this approximated data obtained by preliminary computations allow understanding the compulsory requirement of introducing new management practices and regulations for reducing the contamination of the area around Monteagudo, particularly due to the final disposal of the waste.

3.4. The social survey to the students of Monteagudo

A sample of 60 high school students were interviewed in order to evaluate public perception on environmental issues and ecological subjects [35]. The questionnaire suggested was built with 20 questions in *Likert* scale and binary responses (Yes-No) and which considered also the possibility that the students do not know the answer. The information gathered would provide information about the perception, the general knowledge and the recycling behaviour of the students. The school is the only existing within the area, and the structure has been built by the Salesian organization in 2006. The students interviewed have an average age of 17.5 years old and the 59% are girls. The questions provided to the students are listed in Table 2 whereas an analysis of the results were introduced by commenting the frequencies obtained.

Table 2

Questions of the social survey

N°	Question	Answers
1	Quantity of waste selected at home	1.Nothing; 2.Something; 3.The half; 4.The majority; 5.Everything; 6.I do not know
2	Who provide the waste collection?	1.Municipality; 2.Private sector; 3. Waste pickers; 4. Women and children; 5.Others
3	Frequency of the collection (per week)	1.One time; 2.two times; 3.three times; 4. Four times; 5. Five times; 6. Never
4	The collection timetable satisfy the citizens	

5	The timetable of the collection service is respected	1.Never; 2.Sometimes; 3.Often; 4.Mostly; 5. Always; 6.I do not know
6	The waste is collected by the waste pickers	
7	Are there sensitivity campaigns into the school?	
8	Are there recycling campaigns provided by the municipality?	
9	Do you use the bin to through the waste?	
10	Does your family use reusable bags?	
11	Are there bins for the waste in the city?	1.Yes; 2. No; 3. I do not know
12	Does the municipality produce compost?	
13	Are there campaigns for the respect of the environment?	
14	Are there strategies for the reduction of the waste into the city?	
15	The structure of the collection systems is clear	
16	I would like to select the waste at home and within the school	
17	Is it the first time that you received information about waste management?	
18	Quality of the sanitation systems	1.Really bad; 2. Bad; 3.Good; 4. Very good; 5. Excellent; I do not know
19	What is the efficiency of the collection systems?	
20	What do you think about the waste management of the city	

The most important information gathered thanks to this social survey is that some households in the city are just applying a selective collection, as a 26% of the interviewed affirmed that are recycling the half or more of the waste produced at home (Question 1). This practice is understandable as few times during the week informal buyers of exploitable materials come in the city in search of recyclable waste selected by the citizens. This represents another reverse logistic practice applied informally (Figure 1). Nevertheless, the service provided by the municipality is not uniform as 40% of the students stated that the collection is applied five times per week, whereas 23% affirmed that it is applied less than 2 times (Question 3). Moreover, collection times are satisfactory for the 60% of the students although there is a relevant percentage that do not agree with the current service provided (Question 4). Similar percentages were obtained also concerning the informal sector which works within the city. The 33% of the sample interviewed affirmed that the informal pickers do not work in the city while the 36% stated that they work only sometimes (Question 6), giving indication of low awareness about solid waste management issues and recycling practices. More accordance was achieved for the question related to the sensitive campaign within the school (Question 7): 72% of the students answered that such campaigns are provided only sometimes, in accordance with the municipal practices. Despite that, it is of interest the result obtained for the question ‘Would you like to select the waste within the school and at home?’ (Question 16) as the 83% of the students responded ‘Yes’, providing a good signal on the willingness to introduce the principle of the circular economy into the local context.

4. Discussion

Monteagudo represent the typical developing area where environmental preservation do not enter within public regulation and awareness since pollution effects are not yet evident and consequently environmental issues are not perceived as a real concern for the community. Indeed pollution to water bodies, soils and the air around the city are not yet monitored since no specific illnesses due to environmental contamination are spreading. However, the river that crosses the city and the aquifers are surely contaminated as the infiltration of the rain into the open dump is constant and increase during the rainy season. This water is used for cultivating the food used in the city, sanitary uses and breeding, therefore citizens are indirectly threats by pollutants. Moreover, open burning is really common outside the neighbourhoods, resulting in atmospheric contamination and direct hazards to human health, although are determined by various combinations of weather and climate factors [36-38]. Despite that, solid waste mismanagement is not fully recognized by the citizens, as open dumping is not considered as a real problem, like also suggested by the answers given by the social survey.

Solutions are required in short terms as environmental pollution is starting to be irreversible since the cost for site reclamation represent a serious barrier for low-income regions like Monteagudo. International Cooperation, private inclusion and introduction of integrated regulations are a sustainable way to overcome such issues. Indeed, know-how and technological facilities suited for the context can be provided thanks to international aids. The application of the 3Rs (Reuse, Recovery, Recycling) principle allows introducing a formal reverse logistic systems improved by the private sector and can be a suitable way for improving the economic situation of the area, where energy and primary resources are required. Moreover, selective collection and correct management practices are rights for local citizens which should receive an easy operated system provided by the municipalities [6, 39-41]. In this framework Bolivia national regulation started to provide a few answers in 2015, when the first Environmental Law about solid waste management were redacted. However, many sustainable activities should be applied, involving all international and local stakeholders.

5. Conclusions

This paper introduced the issues concerning solid waste management typical of developing countries. A Bolivian case study was presented, highlighting main problems and barriers for a low-middle income region for developing a sustainable solid waste management. So the paper contributed to the provision of an original research for evaluating environmental worries, social equity and management issues concerning solid waste collection and final disposal.

Monteagudo is facing with many environmental issues due to open dumping and solid waste mismanagement. However, low public awareness on ecological

themes and poor economic funds do not allow introducing sustainable systems and facilities to treat and recovery solid waste materials. Indeed, open burning and bury practices are widespread within the area whereas the municipality do not encourage material recycling.

As a result, Bolivian environment is facing with worrisome mismanagement practices concerning solid waste management and ecosystem preservation, like also happen within the majority of low-income countries. International cooperation, waste pickers formalization, private sector involvement and stakeholder inclusion seems to be the right way for solving such issues, although it must be applied in short terms in order to prevent higher economic misspend and irreversible environmental contamination.

Acknowledgments

The authors wish to thank the Mayor of Monteagudo, Tito Ronald Aramayo Carballo, and all the members of the Municipality for the support on the information required for the study. The authors are also very grateful to Mr. Antonio Ferronato for the logistic support.

R E F E R E N C E S

[1]. *M. Vaccari, V. Torretta, C. Collivignarelli,* 2012. Effect of improving environmental sustainability in developing countries by upgrading solid waste management techniques: A case study. Sustainability **4(11)**, 2012, pp. 2852-2861.

[2]. *W. Leal Filho, L. Brandli, H. Moora, J. Kruopiene, A. Stenmarck, 2016.* Benchmarking approaches and methods in the field of urban waste management, Journal of Cleaner Production, **112**, pp. 4377-4386

[3]. *R. Mohee, S. Mauthoor, Z.M.A. Bundhoo, G. Somaroo, N. Soobhany, S. Gunasee,* 2015. Current status of solid waste management in small island developing states: A review, Waste Management, **43**, pp. 539-549

[4]. *L.A.Guerrero, G. Maas, W. Hogland, 2013.* Solid waste management challenges for cities in developing countries. Waste Management **33(1)**, pp. 220-232.

[5]. *A. Castagna, M. Casagranda, A. Zeni, E. Girelli, E.C. Rada, M. Ragazzi, T. Apostol,* 2013. 3R'S from citizens point of view and their proposal from a case-study, UPB Scientific Bulletin, Series D, **75(4)**, pp. 253-264

[6]. *E.C. Rada, C. Zatelli, P. Mattolin,* 2013. Municipal solid waste selective collection and tourism, Transactions on Ecology and the Environment, **180**, pp. 187-197.

[7]. *G. De Feo, S. De Gisi,* 2010. Public opinion and awareness towards MSW and separate collection programmes: A sociological procedure for selecting areas and citizens with a low level of knowledge, Waste Management, **30(6)**, pp. 958-976.

[8]. *S. Sakai, H. Yoshida, Y. Hirai, M. Asari, H. Takigami, S. Takahashi, K. Tomoda, M.V. Peeler, J. Wejchert, T. Schmid-Untersehr, A.R. Douvan, R. Hathaway, L.D. Hylander, C. Fischer, G.J. Oh, L. Jinhui, N.K. Chi,* 2011. International comparative study of 3R and waste management policy developments, Journal of Material Cycles and Waste Management, **13(2)**, pp. 86-10.

[9]. *V. Martinez-Sanchez, M.A. Kromann, T.F. Astrup,* 2015. Life cycle costing of waste management systems: Overview, calculation principles and case studies, Waste Management, **36**, pp. 343-355.

[10]. *M. Ragazzi, R. Catellani, E.C. Rada, V. Torretta, X. Salazar-Valenzuela*, 2014. Management of municipal solid waste in one of the Galapagos Islands. Sustainability **6(12)**, pp. 9080-9095.

[11]. *K. Sandhu, P. Burton, A. Dedekorkut-Howes*, 2017. Between hype and veracity; privatization of municipal solid waste management and its impacts on the informal waste sector, Waste Management, **59**, pp. 545-556

[12]. *R.M. Atencio Pérez, J.A. Reyes-López, J.A. Guevara-García*, 2013. Environmental risk assessment in a garbage dump with burning, Revista Internacional de Contaminacion Ambiental, **29(3)**, pp. 107-117.

[13]. *D.C. Wilson, A.O. Araba, K. Chinwah, C.R. Cheeseman*, 2009. Building recycling rates through the informal sector. Waste Management, **29(2)**, pp. 629-635.

[14]. *D. Bleck, W. Wettberg*, 2012. Waste collection in developing countries–Tackling occupational safety and health hazards at their source. Waste Management **32(11)**, pp. 2009-2017.

[15]. *K. Ravindra, K. Kaur, S. Mor*, 2016. Occupational exposure to the municipal solid waste workers in Chandigarh, India, Waste Management and Research, **34(11),** pp. 1192-1195

[16]. *R.N. Cunningham, C.D. Simpson, M.C. Keifer*, 2012. Hazards faced by informal recyclers in the squatter communities of Asunción, Paraguay, International Journal of Occupational and Environmental Health, **18(3)**, pp. 181-187

[17]. *G. De Feo, I.D. Williams, 2013.* Siting landfills and incinerators in areas of historic unpopularity: Surveying the views of the next generation. Waste Management **33(12)**, pp. 2798-2810.

[18]. *N. Ferronato, M. Bezzi, M. Zortea, V. Torretta, M. Ragazzi, 2016.* An interdisciplinary approach for introducing sustainable integrated solid waste management system in developing countries: the case of La Paz (Bolivia), Procedia Environmental Science, Engineering and Management **3(2)**, pp. 71-81.

[19]. *E.C. Rada, C. Bresciani, E. Girelli, M. Ragazzi, M. Schiavon, V. Torretta*, 2016. Analysis and measures to improve waste management in schools, Sustainability, **8(9)**, pp. 840-852.

[20]. *S. Lonkar, Z. Fu, M. Wales, M. Holtzapple*, 2017. Creating Economic Incentives for Waste Disposal in Developing Countries Using the MixAlco Process, Applied Biochemistry and Biotechnology, **181(1)**, pp. 294-308

[21]. *G. Vujic, N. Stanisavljevic, B. Batinic, Z. Jurakic, D. Ubavin*, 2017. Barriers for implementation of "waste to energy" in developing and transition countries: a case study of Serbia, Journal of Material Cycles and Waste Management, **19(1)**, pp. 55-69

[22]. *P. Peerapong, B. Limmeechokchai*, 2016 Waste to electricity generation in Thailand: Technology, policy, generation cost, and incentives of investment, Engineering Journal, **20(4)**, pp. 171-177

[23]. *K. Laohalidanond, P. Chaiyawong, S. Kerdsuwan, 2015*. Municipal Solid Waste Characteristics and Green and Clean Energy Recovery in Asian Megacities, Energy Procedia, **79**, pp. 391-396

[24]. *V. Torretta, E.C. Rada, M. Ragazzi, E. Trulli, I.A. Istrate, L.I. Cioca*, 2015. Treatment and disposal of tyres: Two EU approaches. A review. Waste Management **45**, 152-160.

[25]. *S. Kerdsuwan, K. Laohalidanond, W. Jangsawang*, 2015. Sustainable Development and Eco-friendly Waste Disposal Technology for the Local Community, Energy Procedia, **79**, pp. 119-124

[26]. *E.A. Flores,* 2015. Study of the solid waste composition within the municipality of Monteagudo. HELVETAS, Swiss Intercooperation.
[27]. *J. Aleluia, P. Ferrão,* 2016. Characterization of urban waste management practices in developing Asian countries: A new analytical framework based on waste characteristics and urban dimension, Waste Management, **58**, pp. 415-429.
[28]. *J.A.M. Sepúlveda,* 2016. Outlook of municipal solid waste in Bogota (Colombia), American Journal of Engineering and Applied Sciences, **9(3)**, pp. 477-483.
[29]. *M.D.C. Espinosa Lloréns, M.L. Torres, A.P. Arrechea, L.A.F. García, S.D. Aguirre,* 2011. Cuban research in municipal solid waste, Waste Management and Environmental Remediation, pp. 125-175
[30]. *J. Nithikul, O.P. Karthikeyan, C. Visvanathan*, 2011. Reject management from a mechanical biological treatment plant in Bangkok, Thailand. Resources, Conservation and Recycling **55(4)**, pp. 417-422.
[31]. *T. Hazra, S. Goel*, 2009. Solid waste management in Kolkata, India: Practices and challenges. Waste Management **29(1)**, pp. 470-478.
[32]. *M. Sharholy, K. Ahmad, R.C. Vaishya, R.D. Gupta*, 2007. Municipal solid waste characteristics and management in Allahabad, India. Waste Management, **27(4)**, pp. 490-496.
[33]. V. *Torretta*, N. *Ferronato*, I.A. *Katsoyiannis*, A.K. *Tolkou*, M. *Airoldi*, 2016. Novel and Conventional Technologies for Landfill Leachates Treatment: A Review. Sustainability, **9(1)**, 9
[34]. *G. De Feo, S. De Gisi, M. Galasso*, 2012. Rifiuti Solidi, Progettazione e gestione di impianti per il trattamento e lo smaltimento. Ingegneria Sanitaria Ambientale. Ed. Dario Flaccovio. ISBN 978-88-579-0133-6
[35]. N. *Ferronato*, C. *D'Avino*, M. *Ragazzi*, V. *Torretta*, G. *De Feo*, 2017. Social Surveys about Solid Waste Management within Higher Education Institutes: A Comparison. Sustainability, **9(3)**, 391.
[36]. *G. Ionescu, D. Zardi, W. Tirler, E.C. Rada, M. Ragazzi*, 2012. A critical analysis of emissions and atmospheric dispersion of pollutants from plants for the treatment of residual municipal solid waste. UPB Scientific Bulletin, **74(4)**, pp. 227-240.
[37]. *A.S. Nagpure, A. Ramaswami, A. Russell,* 2015. Characterizing the Spatial and Temporal Patterns of Open Burning of Municipal Solid Waste (MSW) in Indian Cities, Environmental Science and Technology, **49(21)**, pp. 12911-12912.
[38]. *J.A. Valencia, A. Espinosa, A. Parra, M.R. Peña,* 2011.Perception of risk arising from atmospheric emissions from an open solid-waste disposal site, Revista de Salud Publica, **13(6)**, pp. 930-941
[39]. *R. Ciudin, C. Isarie, L. Cioca, V. Petrescu, V. Nederita, E. Ranieri*, 2014. Vacuum waste collection system for an historical city centre. UPB Scientific Bulletin, series D, **76(3)**, pp. 215-222.
[40]. *T.B. de Oliveira, A.C. Galvão Junior,* 2016. Municipal planning in solid waste management and organization of selective collection, Engenharia Sanitaria e Ambiental, **21(1)**, pp. 55-64
[41]. *L.I.B. Buque, H. Ribeiro,* 2015. Overview of the selective waste collection with pickers in Maputo municipality, Mozambique: Challenges and perspectives, Saude e Sociedad, **24 (1)**, pp. 298-307.