6th International Conference on Sustainable Solid Waste Management

http://www.naxos2018.uest.gr
Committees

Scientific Committee

Maria Loizidou, National Technical University of Athens, Chair
Abdul-Sattar Nizami, King Abdulaziz University
Adam Smolinski, Central Mining Institute
Adela Galvin, University of Cordoba
Ahmed El-Gendy, American University in Cairo
Aleksandra Djukić-Vuković, University of Belgrade
Alexandra Ribeiro, Universidade Nova de Lisboa
Amane Jada, IS2M-CNRS
Ana Jiménez-Rivero, Universidad Politécnica de Madrid
Anastasia Zabaniotou, Aristotle University of Thessaloniki
Anastasios Zouboulis, Aristotle University of Thessaloniki
Andrea Capodaglio, University of Pavia
Andres Illanes, Universidad Católica de Valparaíso
Ange Nzihou, École des Mines d'Albi
Antonis Mavropoulos, International Solid Waste Association
Antonis Zorbas, Open University of Cyprus
Apostolos Koutinas, Agricultural University of Athens
Apostolos Vlyssides, National Technical University of Athens
Barbara Ruffino, Politecnico di Torino
Carlos Ariel Cardona Alzate, Universidad Nacional de Colombia sede Manizales
Carol S.K. Lin, City University of Hong Kong
Celia Dias-Ferreira, Polytechnic of Coimbra
Chew-Tin Lee, University Technology of Malaysia
Christopher Cheeseman, Imperial College
Christopher Koroneos, National Technical University of Athens
Costas Costa, Cyprus University of Technology
Costas Velis, University of Leeds
David Bolzonella, University of Verona
David Newman, World Biogas Association
Dimitrios Kaliampakos, National Technical University of Athens
Dimitrios Komilis, Democritus University of Thrace
Dimitrios Malamis, National Technical University of Athens
Dolores Hidalgo Barrio, CARTIF Technology Centre
Evina Katsou, Brunel
Filiz Dilek, Middle East Technical University
Francesco Fatone, Marche Polytechnic University
Francisco Agrela, University of Cordoba
Francisco Omil, Universidad de Santiago de Compostela
Florian Amlinger, European Compost Network
Georgia Labuto, Universidade Federal de Sao Paulo
Gerasimos Lyberatos, National Technical University of Athens
Giuseppe Mancini, University of Catania
Gregorio Antollin, University of Valladolid
Grigoris Itskos, Purdue University
Hussam Jouhara, Brunel University
Ioannis Skladas, Technical University of Denmark
Isam Janajreh, Masdar Institute
Jader Busato, Universidade de Brasilia
Jale Yanik, Ege University
Jiri Hrebiec, Masaryk University
Joan Dosta, University of Barcelona
Joseph Patrick Hettiaratchi, University of Calgary
Joseph Zeaïter, American University of Beirut
Juan Antonio Baeza Labat, Universitat Autonoma de Barcelona
Justo García-Navarro, Universidad Politécnica de Madrid
Katarzyna Chojnacka, Wroclaw University of Technology
Katherine-Joanne Haralambous, National Technical University of Athens
Katia Lasaridi, Harokopio University
Kiran Thakur, Hefei University of Technology
Konstantinos Aravosis, National Technical University of Athens
Konstantinos Moustakas, National Technical University of Athens
Laurent Lemee, Université de Poitiers
Lidia Lombardi, Università degli Studi Niccolò Cusano - Telematica Roma
Lionel Limousy, Université de Haute-Alsace
Lorna Anguiano, Brunel University
Luben Tzankov, Technical University of Sofia
Luciano Matos Queiroz, University of Bahia
Marc Deshusses, Duke University
Marco Baratieri, Free University of Bolzano
Maria Zachariou-Dodou, Institute of Environment & Sustainable Development
Mauro Majone, Sapienza University of Rome
The socio-economic impact assessment timeline point of departure for persistent organic pollutants (POPs) in Serbia

Jelena Milic1*, Marijana Ćurčić2, Zvonko Brnjac3, Aleksandar Jovović4, Jasmina Randelović5, Katarina Krinulović6, Hristina Stevanovic-Carapina7

1* Institute of Chemistry, Technology and Metallurgy, Centre for Ecotoxciology, Studentski trg 16, Belgrade, Serbia
2 University of Belgrade-faculty of Pharmacy, Department of Toxicology “Akademik danilo Soldatović”, Vojvode Stepe 450, 11221 Belgrade, Serbia
3 Economics Institute, Kralja Milana 16, Belgrade, Serbia
4 Faculty of Mechanical Engineering, Kraljica Marija 16, Belgrade, Serbia
5 Chemical expert, Vojislava Ilića 18, Belgrade, Serbia
6 SECPA coordinator and Chemical expert, Milošev Kladenac 16, Belgrade, Serbia
7 EDUCONS University, VojVode Putnika 47, Sremska Kamenica, Serbia

Abstract: Assessing the Socio-Economic impact of dangerous chemicals including persistent organic pollutants (POPs) as its specific segment, includes analysis of its impacts on human health, on environment and on local economic development. There are abundant evidences of these effects of the dangerous chemicals throughout the world provided by number of researches. According WHO research (2011) they are causing around 4.9 million of deaths (8.3% out of the total number) and 86 million Disability-Adjusted Life Years (5.7% out of the total number); according to the very conservative estimates, 20% of deaths by cancer are the consequence of the cancerous effects of chemicals in the workplace. Those substances have adverse effects to the environment, by making the use of natural resources more difficult and thus have an adverse impact on the ecosystem and causing additional costs to bringing it back into balance. Their impact on economic development is manifested primarily through reduced productivity of society due to the impairment of the health of the population and natural resources. The specific research which results are presented in this article has been focused on impact of POPs chemicals on human health, specifically on the one effecting cancers. This impact has been presenting in the very general terms through estimation of the monetized cost effects for treating cancers and assumption of the carcinomas effecting by POPs in Serbia. These costs estimation based on available data provided from the National Health Insurance Fund (RFZO) gives amounts ranging from 4.7 to 5.2 million EUR.

Keywords: Socio Economic Assessment, POPs, Environment, Economic development Impact, Human Health

*corresponding author: j.milic@chem.bg.ac.rs

1. Introduction

The Stockholm Convention on Persistent Organic Pollutants (POPs) aims to restrict and ultimately eliminate production, use, release, and storage of POPs chemicals, and at this point Convention is listing 29 chemicals meeting the criteria which are: adverse effects to human health, persistence, bio-acumulation and potential for long-range environmental transport [1]. POPs could have significant economic consequences, which will affect economic growth as well as welfare. In the frame of Stockholm convention, chemicals are divided in three groups: pesticides, industrial chemicals and unintentionally produced chemicals [1].

1.1. POPs Chemicals in Serbia

According to Updated National Implementation plan (UNIP), it is established there is no production, use, import or export of POPs chemicals, divided in pesticides, industrial chemicals and unintentionally release ones [3].

A quantity of POPs pesticides existence of which was identified in 2014 was 1.35 tons [4]. The amounts of POPs industrial chemicals are assessed for polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), hexabromocyclododecane (HBCDD) and perfluorooctanesulfonic acid (PFOS). Based on the results of the detailed inventory of the PCB contaminated transformers, as well as on additional testing performed, it is assessed that is approximately 4480 PCB transformers are contaminated, 585 tons of oils from transformers and around 4200 of low voltage transformers. The quantity of generated PCB waste accounts for 112.2 tons and the amount of PCBs waste exported in the same is 419 tons [3]. In 2013, the estimated amount of PBDEs in vehicles in Serbia was around 13 tons; while the estimated amount of PBDE in cathode ray tube casings in electrical and electronic equipment ranges from 46.9 to 136.9 tons. The assessed overall quantity of HBCD on the market in Serbia is 37.3 tons, with uncertainty due to unavailability of certain portion of data. Serbia does not produce PFOS chemicals or their derivatives and has not in the last 10 years imported PFOS chemicals or their derivates. However, some finished and semi-finished products imported to the Serbia potentially contain PFOS chemicals like teflon and teflon based products. Presence of fire fighting foams containing PFOS was identified in the past, and most of foam was spent during NATO bombing in 1999 [4]. Based on the results of the preliminary inventory of unintentionally produced POPs chemicals these are emitted to the environment from different sources: open burning processes, PCBs in electrical equipment, and production of electrical and heating energy. Furthermore, in Serbia there are over 3,000 unsanitary landfills scattered around the country [4].

1.2. Definition and Contents of the SEIA

The socio-economic impact assessment (SEIA) of hazardous chemicals is defined as a systematic assessment of a potential impact of economic and other activities to all parts of society, including local communities and groups, the civil society, the private and public sector, etc. [5,6]. The SEIA is a tool for analyzing and managing intended and unintended influences either positive or negative, interventions (policies, programmes, plans and projects) and any other social change initiated by these interventions [6]. Impacts could be classified as impact on the health, on the environment and on the economic development [5,6].

One of the most important efforts to quantify the adverse effects of chemicals on human health has been made by the World Health Organization (WHO) [7]. The adverse impact of chemicals on human health has been quantified with the help of two basic indicators: the number of deaths and Disability-Adjusted Life Years (DALY) number, that is, the number of lost days to deteriorating health and illnesses. According to estimates presented in this study, in 2004, around 4.9 million of deaths (8.3%) and 86 million DALY (5.7%) were the consequence of effects of the analysed chemicals on the environment and humans. These indicators include the impact of fossil fuel combustion and air pollution. Additionally, effects of chemicals in the work place, acute chemical poisoning and positioning with pesticides have caused 375, 240 and 186 thousand deaths, respectively. The magnitude and importance of these effects can be presented even more clearly by comparing them with other known causes of deaths which are recorded with relatively more reliable data [7].

Also, there have been numerous attempts to monetize the adverse effects of hazardous chemicals, that is, to present them in financial terms. These attempts are characterized by different approaches which reflect in different methodologies applied, different scope of research and choice of chemicals (individual or groups) which have been researched and secondly, their results are very difficult to compare [6].
Below, portion of the obtained results which pertain to the impact of hazardous chemicals such as POPs (pesticides primarily) which have been very frequently subject to these research activities (Table 1) [8].

### Table 1. Results of International Research

<table>
<thead>
<tr>
<th>Scope</th>
<th>Chemical</th>
<th>Health Effect</th>
<th>Monetized effects</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>Pesticides</td>
<td>Pesticide poisoning</td>
<td>9.7 million EUR of hospital costs and 2.5 million EUR of losses due to lost working hours</td>
<td>Blainey et al., 2008 [9]</td>
</tr>
<tr>
<td>Germany</td>
<td>Pesticides</td>
<td>Acute pesticide poisoning</td>
<td>USD $ 14 million</td>
<td>Waibel et al., 1999 [10]</td>
</tr>
<tr>
<td>USA</td>
<td>Pesticides</td>
<td>Acute pesticide poisoning, cancer and other chronic effects, death cases</td>
<td>USD $ 787 million</td>
<td>Pimentel et al., 1992 [11]</td>
</tr>
<tr>
<td>USA</td>
<td>Pesticides</td>
<td>Acute pesticide poisoning</td>
<td>USD $ 8 million of hospital costs and USD $ 17million due to lost working hours</td>
<td>Pimentel et al., 1992 [11]</td>
</tr>
<tr>
<td>Ecuador, Carchi Province</td>
<td>Pesticides</td>
<td>Acute pesticide poisoning</td>
<td>Cost of private medical treatments: USD $ 17 per case</td>
<td>Yanggen et al., 2003 [12]</td>
</tr>
<tr>
<td>Zambia, Kuala Lumpur</td>
<td>Chemicals used in cotton fields</td>
<td>Acute pesticide poisoning</td>
<td>USD $ 2.1 million (lost working hours due to sick leaves 51.1%, medical treatment costs 40.7%, transport and other costs 8.1%)</td>
<td>Bwalya, 2010 [14]</td>
</tr>
</tbody>
</table>

Research activities of this type put special emphasis on determining the effects of chemicals in the work place. Thus the research of the Pickvance et al. (2005) showed that if the application of measures specified by the framework of the EU REACH Regulation 1907/2006 (Registration, Evaluation, Authorisation and Restriction of Chemicals), would cease to exist, in the period of next 30 years, additional 90.9 billion EUR would be generated as costs which include costs of medical treatments, effects of reduced productivity, reduced quality of life due to chronic illnesses such as pulmonary diseases and dermatitis [15]. On the other hand, increased costs of chemical, and other affiliated industries resulting from the application of REACH measures have been estimated at € 2.8 – € 5.2 billion, for the period of 15 years.

The aim of this study was to analyze socio economic impact of POPs chemicals in Serbia on human health, as well as impact to environment and assess the cost of illness based on loss of life, costs of contaminated sites clening and costs for actions needed for prevention of this impact on human health and environment. This study assesses the health and environmental benefits in 5-year phase out scenario from the aspects of desposal, decontamination, reduction and prevention of POPs chemicals to eneter environment. For the best of authors’ knowledge, this the first time such analysis has been done.

2. Experimental
Bearing in mind that there are no specific data or researches based on which the registered cases of illness could be classified by cause, it is very difficult to provide the amount of stated costs which might be directly linked with POPs. In the present work authors tend to give preliminary estimations of costs under a three pillar approach:

- To analyse Health impact of POPs in Serbia. Given the limited resources (financial, human and time) available for subject research, the health impact assessment in Serbia in this study put the special emphasis on illnesses labelled with following codes of the International Classification of Illnesses: carcinomas C15-C26, C34, C43, C44, C46, C50, C73, C81-C84 and non-carcinomas K71-73, E03.2, E03, G11, G40-G47, D80, D82) [16].

- To analyze environmental impact of POPs in Serbia from government official data and scientific researchers, and predicted cost of disposal of and decontamination for 5 year phasing out scenario, using methodology given in Updated NIP as well as guidelines given in Zhu et al. (2016) [17].

- To assess the socio-economic impact of POPs chemicals in Serbia, we chose to use: (1) medicals cost as share of GDP, and (2) benefit – cost ratio (BCR)-the BCR, in 5 years phase out scenario. Share of medical cost in GDP represent the environmental POPs exposures contribution to health costs by exceeding percentage of GDP. The ratio should be greater than 1.0 in order to proposed measures be acceptable.

3. Results & Discussion

3.1. Health impact of POPs in Serbia

Persistant organic pollutants cause a variety of adverse health effects, including reproductive, developmental, endocrine, and carcinogenic effects [18-20]. The primary route of exposure for the human population is through contaminated food, but other routes include contaminated air, water, proximity to POPs-contaminated sites, dermal contact with everyday use products which could contain mostly PFOS or PBDE. Furthermore, newborns are affected by POPs transfer through the placenta and breast milk to [21,22].

In the Serbian NIP is stated that daily PCB intake of an adult weighing 70 kg equals 0.79 μg (1.1% of acceptable daily intake [ADI]), based on POPs compounds concentrations in foodonsumption in atmosphere and soil in the town of Novi Sad [2]. Petrović et al. (2008) assessed dioxin intake via food in Serbian population and result was 3.14 pg TEQ/kg/day, which is more than the value recommended for EU by the Scientific Council on Food, set on 2 pg TEQ/kg/day, but is still in the range recommended by the WHO of 1-4 pg TEQ/kg/day, having in mind that WHO tends to achieve the intake of 1 pg TEQ/kg/day, tehrefore 3.14 pg TEQ/kg/day can be taken as indicator of the need for raising awareness [2, 23]. Škrbić and Đurišić-Mladenović (2007) examinated occurrence of six indicator PCBs in 35 composite samples of crop products and by-products of food processing industry and assess the dietary intake by Serbian adult population. The average daily intake of sum of PCBs was assessed to be 172.2 ng using a mean weight of 60 kg for the general population in Serbia. The wheat-based products contributed largely (141 ng/day) to the estimated value [24, 25]. Another study releaved the results of monitoring DDT, HCH and PCBs in early human milk during period 1982–2009, which indicated that concetrations of POPs had decreasing trend, only PCBs had with two small peaks in 2003 and 2009. Although the estimated daily intake of PCBs was far below the upper limit for daily milk products in Serbia, its two increases is a clear indication of environmental influx of these compounds after the 1994 measurements [26]. Civil society
organisation Arnika published report on dioxin congener patterns for two samples of free range chicken eggs from Obrenovac (Serbia) which were specific and showed the prevalence of PCDD congeners over other congeners in samples (5.2 and 2.2 pg PEQ/g of fat PCDD/F) which points that chemical production in nearby of Obrenovac could be a potential source of contamination [27].

At this particular point, Serbia does not have any official data or specified researches based on which the registered cases of illness could be classified by cause. For the purpose of initial estimation, we have identified potential effects of POPs chemicals on the health of people (Table 4) and highlighted critical effects and cancer [28,29]. Beginning with identified or potential cancers and other more serious illnesses caused by POPs, we put special emphasis on illnesses labelled with codes listed in Table 2. The review of diseases and their corresponding codes is presented in the Table 2.

Table 2. Review of POPs chemicals and related effects on human health

<table>
<thead>
<tr>
<th>POPs Chemicals and type</th>
<th>Effects</th>
<th>Critical Effects</th>
<th>CODE of Carcinoma</th>
<th>CODE of other effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aldrin *P</td>
<td>Neurological disorders, carcinogenic, reproductive, endocrine</td>
<td>CNS excitation; transaminase; suspected human carcinogen</td>
<td>K71-K73</td>
<td></td>
</tr>
<tr>
<td>Dieldrin</td>
<td>Neurological disorders, carcinogenic, reproductive, endocrine</td>
<td>CNS excitation; transaminase; suspected human carcinogen</td>
<td>G40-G47</td>
<td></td>
</tr>
<tr>
<td>Hexabromobiphenyl (HBB) **IC</td>
<td>Skin changes (chlorine, hyperpigmentation); neurological effects (muscle weakness and spasms); carcinogenic</td>
<td>Thyroid gland, T4 decrease, suspected human carcinogen (breast, digestive system and lymphoma)</td>
<td>C50, C15-C26, C81-C84 E03</td>
<td></td>
</tr>
<tr>
<td>Alpha-Hexachlorocyclohexane (HCH) P</td>
<td>Neurological disorders, carcinogenic, reproductive, endocrine</td>
<td>Hyperexcitability, epilepsy, convulsions, liver, suspected human carcinogen</td>
<td>K71-K73</td>
<td></td>
</tr>
<tr>
<td>Beta-Hexachlorocyclohexane (HCH) P</td>
<td>Neurological disorders, carcinogenic, reproductive, endocrine</td>
<td>Hyperexcitability, epilepsy, convulsion and ataxia</td>
<td>G11</td>
<td></td>
</tr>
<tr>
<td>Mirex</td>
<td>Hepatotoxicity, suspected human carcinogen</td>
<td>K71-K73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endosulfan and isomers P</td>
<td>Neurological effects</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlordane P</td>
<td>GIT diseases, neurological, liver, carcinogenic</td>
<td>Hepatotoxicity, suspected human carcinogen</td>
<td>K71-K73</td>
<td></td>
</tr>
<tr>
<td>Endrin P</td>
<td>CNS (Central Nervous System), etc.</td>
<td>CNS convulsions</td>
<td>G40-G47</td>
<td></td>
</tr>
<tr>
<td>Tetrabromodiphenyl ether and pentabromodiphenyl ether (penta-BDE) IC</td>
<td>Thyroid gland, neurological growth and development, liver</td>
<td>Neurobehavioural effects, thyroid hormones homeostasis, suspected human carcinogen</td>
<td>P05-P08, E03.2</td>
<td></td>
</tr>
<tr>
<td>hexabromodiphenyl ether and heptabromodiphenyl ether (octa-BDE) IC</td>
<td>Neurotoxicity, liver, thyroid, growth and development</td>
<td>Hepatotoxicity (enzyme induction), suspected human carcinogen</td>
<td>K71-K73</td>
<td></td>
</tr>
<tr>
<td>Pentachlorobenzene P, IC</td>
<td></td>
<td>Hepatotoxicity, nephrotoxicity</td>
<td>K71-K73</td>
<td></td>
</tr>
<tr>
<td>Chlordecone P</td>
<td></td>
<td>Renal effects, suspected human carcinogen</td>
<td>N0-N19</td>
<td></td>
</tr>
<tr>
<td>Heptachlor P</td>
<td>Neurological, liver, reproductive, growth and development</td>
<td>Nervous and immune system development, suspected human carcinogen</td>
<td>D80-D82</td>
<td></td>
</tr>
<tr>
<td>Hexachlorobenzene (HCB) P, IC</td>
<td></td>
<td>Hepatotoxicity, suspected human carcinogen (thyroid, sarcomas)</td>
<td>C73, C46 K71-K73</td>
<td></td>
</tr>
<tr>
<td>Lindane P</td>
<td></td>
<td>Immunological effects and toxicity to reproduction, growth and development</td>
<td>P05-P08</td>
<td></td>
</tr>
<tr>
<td>PCB IC</td>
<td>Skin changes (chlorine, hyperpigmentation); neurological effects (muscle</td>
<td>Immunological effects, proneness to respiratory system infections, suspected human carcinogen</td>
<td>D80-D82</td>
<td></td>
</tr>
<tr>
<td>POPs Chemicals and type</td>
<td>Effects</td>
<td>Critical Effects</td>
<td>CODE of Carcinoma</td>
<td>CODE of other effects</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------</td>
<td>------------------</td>
<td>-------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Toxaphene P</td>
<td>weakness and spasm; carcinogenic</td>
<td>Fatty liver disease, tubular necrosis, suspected human carcinogen</td>
<td>K73, N11</td>
<td></td>
</tr>
<tr>
<td>DDT P</td>
<td>Nervous system (fatigue, convulsions), fertility, pregnancy maintenance, lactation duration</td>
<td>Hepatotoxicity, suspected human carcinogen</td>
<td>K71-K73</td>
<td></td>
</tr>
<tr>
<td>PFOS, PFOSA IC</td>
<td></td>
<td>Fetus development, reproductive system of the foetus, neuroendocrine, suspected human carcinogen (bladder cancer)</td>
<td>P05-P08</td>
<td></td>
</tr>
<tr>
<td>PCDD IC</td>
<td>Chlorine, liver, thyroid, growth and development, immune, reproductive, carcinogenic</td>
<td>Toxicity to growth and development (especially of reproductive system), suspected human carcinogen (sarcomas, lymphomas, respiratory system, gastrointestinal system)</td>
<td>C46, C81-C84, C34, C26</td>
<td>P05-P08</td>
</tr>
<tr>
<td>PCDF IC</td>
<td>Chlorine, liver, thyroid, growth and development, immune, reproductive, carcinogenic</td>
<td>liver (increased bilirubin, AST, ALT, TG), suspected human carcinogen (skin and liver)</td>
<td>C43, C44, C22</td>
<td>K71-K73</td>
</tr>
</tbody>
</table>

*P – Pesticides; **IC – Industrial Chemicals

Based upon the official data of the Republic Health Insurance Fund, Table 4 shows the costs of treatment for two groups of diseases: G1 group which consists of carcinogenic diseases and G2 group which comprises non-carcinogenic diseases, which potentially may be the consequence of exposures to POPs [29]. This assessment includes 5-year period, as a set period for further socio-economic analysis.

**Table 3. The cost of medical treatment for diagnosed G1 (carcinomas) diseases which are related to POPs chemicals from 2011 to 2015.**

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of treated G1 persons without repetition</td>
<td>118,720</td>
<td>114,678</td>
<td>109,644</td>
<td>126,337</td>
<td>125,908</td>
</tr>
<tr>
<td>Cost of G1 patient treatment</td>
<td>1,482</td>
<td>1,360</td>
<td>1,431</td>
<td>1,455</td>
<td>1,492</td>
</tr>
<tr>
<td>Total cost of G1 treatment (mill EUR)</td>
<td>175.9</td>
<td>156.0</td>
<td>156.9</td>
<td>159.8</td>
<td>158.6</td>
</tr>
</tbody>
</table>

The costs related to the treatment of G1 group diseases in Serbia in the observed period (2011-2013) ranged from 175.9 to 158.6 million EUR while the costs referring to individual cases between rather stable and oscillated around of 1.5 thousand EUR (Table 3). The costs for treatment of diseases from G2 group in the provided period were between 237.3 260.1 million EUR and the cost of treatment of diseases from G2 group in given period was between 1.0 thousand to 0.9 thousand EUR per patient (Table 4).

**Table 4. The cost of medical treatment for diagnosed G2 (non-carcinomas) diseases which are exrelated to POPs chemicals**

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of treated G2 persons without repetition</td>
<td>234,943</td>
<td>237,931</td>
<td>256,399</td>
<td>353,066</td>
<td>347,482</td>
</tr>
<tr>
<td>The cost of G2 patient</td>
<td>1,010</td>
<td>894</td>
<td>909</td>
<td>835</td>
<td>886</td>
</tr>
<tr>
<td>Total cost of G2 treatment (mill EUR)</td>
<td>237.3</td>
<td>212.6</td>
<td>233.0</td>
<td>256.4</td>
<td>260.1</td>
</tr>
</tbody>
</table>

Calculation was conducted according to the official data of National Bank of Serbia, with annual average exchange rate of dinar to euro.

6
As is the case with many environmental pollutants, it is uncertain to establish that illness or diseases are directly connected to exposure to a specific or to a group of POPs. It is underscored by the fact that POPs rarely occur as a single compound, and that individual field studies are insufficient to provide compelling evidence of certain relationship between cause and effect. Therefore, estimations should have the purpose to provide basic idea on the level of these costs.

WHO indicates that around 20% of carcinomas are caused by hazardous chemicals. If we are to begin with a hypothesis that POPs chemicals might comprise at least 10% (the worst case scenario, half of all chemicals) of the adverse effects of hazardous chemicals or that they are related with approximately 2% of all carcinomas, we may reach rather approximate estimate of costs required for treatment of the aforementioned diseases in Serbia. The fact that the research of the WHO pertains to the cause of carcinogenic diseases which originate from the work place, could mean that the results are underestimated, considering that it might be expected that the exposure is more intense in the work place than in environment in general.

According to this assumption, the costs of medical treatment of carcinogenic diseases which could be connected to POPs in the period from 2011 to 2015 are given in Table 5.

**Table 5. Estimated costs of medical treatment for diseases caused by POPs chemicals**

<table>
<thead>
<tr>
<th>Group</th>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>Total cost of G1 treatment</td>
<td>3,518.9</td>
<td>3,119.7</td>
<td>3,137.9</td>
<td>3,196.0</td>
<td>3,172.5</td>
</tr>
<tr>
<td>G2</td>
<td>Total cost of G2 treatment</td>
<td>4,745.7</td>
<td>4,252.3</td>
<td>4,659.8</td>
<td>5,127.3</td>
<td>5,201.4</td>
</tr>
<tr>
<td>TOTAL (in 1000 of EUR)</td>
<td>8,264.6</td>
<td>7,372.0</td>
<td>7,797.6</td>
<td>8,323.2</td>
<td>8,373.9</td>
<td></td>
</tr>
</tbody>
</table>

As regards the effects on illnesses from the other group (G2) which pertain to non-cancerogenic diseases, it is not possible to present quantitative estimate due to lack of data and research. Nevertheless, for the sake of illustration a very general picture of possible monetized human health effects of POPs, we would get annual estimates ranging from 4.7 to 5.2 million of EUR. The total medical treatment costs of diseases classified under G1 and G2 groups which could be potentially connected to POPs could total between 8.3 and 8.4 million of EUR.

3.2. Environmental impact of POPs in Serbia

The examination of the quality of surface waters and groundwater in accordance with the Programme of Systematic Water Quality Control carried out by the Serbian Environmental Protection Agency. Information received on the status of the waters is the basis for making decisions regarding water management. Continuous monitoring of water quality serves as the relevant source of professional information in the form of the presentation on the state of water resources as well as the basis for protection of water from contamination and for its optimum use.

Analysis of the results regarding the POPs content in river waters in 2012 showed that the most sites (9 out of 54) register lindane. Concentrations of aldrin, chlordane (α,γ), endrin, hexachlorobenzene and polychlorobiphenyls have been below the limit of quantification (LOQ). All maximum concentrations measured were below the prescribed values for parameters containing defined maximum permissible concentrations (Table 6) [30].

**Table 6. POPs in river water**
Analysis of the results regarding POPs contents in 2012 in the sediment shows that PCB congeners have been registered on most sites (8 of 47) in concentrations lower than values defined in the Regulation on the limit values of pollutants in surface water and groundwater and the deadlines for their achievement. Maximum measurement of the hexachlorobenzene concentration was close to the limit of quantification (LOQ) whereas the concentrations of all other substances were below the LOQ (Table 7) [3].

**Table 7. POPs content in water sediments***

<table>
<thead>
<tr>
<th>Substance</th>
<th>CAS number</th>
<th>Limit of quantification (LOQ) (µg/l)</th>
<th>No of locations where POPs have been detected</th>
<th>Maximal measured concentration (µg/l)</th>
<th>Target value (µg/kg)</th>
<th>Maximum permissible concentration (µg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>hexachlorobenzene</td>
<td>118-74-1</td>
<td>0.001</td>
<td>1 of 47</td>
<td>LOQ</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PCB (congeners 28, 52, 101, 118, 138, 153, 180)</td>
<td>1336-36-3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.001</td>
<td>1 of 47</td>
<td>8.8</td>
<td>20</td>
<td>200</td>
</tr>
</tbody>
</table>

* only values where number of location was more than 0 are presented (from UNIP Serbia, 2015)
measured in water and sediment were under the LOQ except for the PCB congeners in the sediment of the Veliki Lug River on the profile of the Bridge on the road to Jagnjilo – 528 µg/kg of sediment [31]. These results indicated contaminated site as a source of PCBs.

After the war conflicts in 1999 and chemical accidents in Kragujevac, Bor, Pancevo and Novi Sad, the public attention has been focused on the pollution of environment and possible consequences on the health of the workers and general population. However, there is still a relatively small number of data on POPs content in environmental samples. Turk et al. (2007) analysed for PCBs, HCHs, DDT and metabolites by active and passive air sampling from three localities in Kragujevac and concentrations were: \( \sum_{PCB} = 39.685 \text{ ng/m}^3 \), \( \sum_{HCH} = 0.309 \text{ ng/m}^3 \) and \( \sum_{DDT} = 0.321 \text{ ng/m}^3 \), respectively where high levels of PCBs was result of transformers destruction during war accident [32].

As a part of ICPDR Joint Danube Survey 2 (2007), higher PFOS concentrations of 20 ng/L have been identified at the confluence of the Morava and Danube [33]. Relatively high concentrations of perfluorononanoic (PFNA) average value of 108 ng/L have been detected in River Tisa. In the same samples perfluoroundecanoic acid (PFUnA), perfluoroctanoic acid (PFOA) and PFOS have been detected in maximum concentrations and even 10 or 3 ng/L [34]. In addition, PFOS chemicals have been detected in higher concentrations in the sediment of the watershed of the Danube near the industrial zone Pancevo downstream from the place of discharge of wastewaters from the zone of oil refinery and petrochemical industry. Downstream from the HIP Petrohemija 130, 170 and 5700 ng/kg of dry substance PFOA, PFHxA and PFOS have been detected, whereas downstream from the NIS Oil Refinery Pancevo values were 76, 66 and 420 ng/kg respectively [35].

In the territory of the Republic of Serbia, 709 potentially contaminated and contaminated sites were identified and recorded in the Cadaster, of which 557 sites are registered and 152 are estimated. Out of 709 sites, 478 are in need of investigation or still to be investigated and 103 are currently under investigation, while 41 sites are in the process of rehabilitation. Rehabilitation and remediation (re-cultivation) are completed on 52 sites where after-care measures are currently being applied. The highest number of registered sources of local soil contamination comes from the municipal waste (43.5%) followed by the exploitation and production of oil (31.7%), locations for passengers and commercial transport (21.6%), industrial waste (7.2%) and from industrial and commercial activities (10.2%) [36].

Presented analysis of the results of the POPs chemicals in environment confirms the importance of adoption of the action plan for disposal of and decontamination thus preventing the further release of POPs in the compartments of environment and food chain. One of the key methodological questions in the process of assessing costs of the action plans for implementation disposal of and decontamination is how to before all as precise as possible determine these costs and then to separate them from other costs of environmental protection. This is even harder because very often influences of POPs chemicals are manifested together with influences of other substances and therefore measures and instruments for their recovery are applied simultaneously. For this reason, special attention was devoted to the separation of costs that are directly and exclusively related to the POPs chemicals. According to methodology given in National Implementation Plan for Stockholm convention it is calculated the total cost of disposal of and decontamination from POPs chemicals in Serbia at 24.6 million EUR (scenario for 5 years phasing out) and the breakdown of cost is given in Figure 1. Finally, it is important to notice that all of the mentioned financial amounts and projections are in fact rough estimations and they represent preliminary assessment that should be additionally specified.
3.3. Socio-Economic impact of POPs chemicals in Serbia

The indicators of the impact of POPs chemicals have on economic activities in this paper are shown as a relative share of GDP (Gross Domestic Product). In that sense costs of pollution is expressed as a percentage of GDP which has been spent or lost in order to remove the consequences of pollution (Table 8) [37].

<table>
<thead>
<tr>
<th>Year</th>
<th>R. Serbia GDP (Billion of RSD)*</th>
<th>(EUR/RSD)**</th>
<th>GDP u billion of EUR</th>
<th>Medical Treatment Costs</th>
<th>Share of Treatment Costs in GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>3,407.6</td>
<td>102.0</td>
<td>33.42</td>
<td>175,900.0</td>
<td>0.53%</td>
</tr>
<tr>
<td>2012</td>
<td>3,584.2</td>
<td>113.1</td>
<td>31.68</td>
<td>156,000.0</td>
<td>0.49%</td>
</tr>
<tr>
<td>2013</td>
<td>3,876.4</td>
<td>113.1</td>
<td>34.26</td>
<td>156,900.0</td>
<td>0.46%</td>
</tr>
<tr>
<td>2014</td>
<td>3,908.5</td>
<td>117.3</td>
<td>33.32</td>
<td>159,800.0</td>
<td>0.48%</td>
</tr>
<tr>
<td>2015</td>
<td>4,043.0</td>
<td>120.7</td>
<td>33.49</td>
<td>158,600.0</td>
<td>0.47%</td>
</tr>
</tbody>
</table>

* Average exchange rate of RSD vs. EUR; **official data of National Bank of Serbia

It is important to note that the adverse human health effects are manifested further in the economic sphere of society mainly through: loss of income due to death of a family member; reduction of income due to reduced working ability caused by illness and increased medical costs and increase of cost of public health. Beside that, adverse effect to environment include lost of biodiversity and decrease of agricultural values and food production as an important sector in Serbian commerce.

Using calculated costs in previous sector/chapters it is possible to calculate Benefit – Cost Ratio (BCR):

$$BCR = \frac{value\ of\ benefits}{value\ of\ costs} = 1.63$$

value of benefits: cost of G1 and G2 treatment for five years (40.131 million EUR; Table 5)
value of cost: cost disposal of and decontamination scenario for 5-year phasing out (24.582 milion EUR; Fig 1).

According to BCR, every 1 EUR of cost will return 1.63 EUR of benefit after 5 years period. It is important to point out that environmental benefits are not possible to monetize due to lack of data and complexity of environmental services, however net benefits could only be increased.

4. Conclusions

In conclusion, measures that must be taken according to UNIP, should get monetized benefits of at least 63% (monetized are costs related to human health and to the nevironment). There is no doubt, that detailed socio-economical analysi would contribute more to identify critical points, the most expensive invetstitions, but at the same time the most beneficial for human healt and to the environment among Serbian population. We will continue with timeline in all important areas in order to follow improvement of our national status as a result of Stockholm convention implementation. Finally, it is important to emphasize that all of the mentioned financial amounts and projections are in fact rough estimations and they represent preliminary assessment that should be additionally specified.

5. Acknowledgement

Authors would like to thank to the Ministry of Environmental protection, Serbian Environmental protection Agency and National Health Insurance Found.

6. References


The socio-economic impact timeline in Serbia for persistent organic pollutants (POPs)


1University of Belgrade-Institute of Chemistry, Technology and Metallurgy, 11000 Belgrade, Serbia
2University of Belgrade-Faculty of Pharmacy, 11000 Belgrade, Serbia
3Faculty for Banking, Insurance and Finance, Belgrade Banking Academy, 11000 Belgrade, Serbia
4Faculty of Environmental Protection, University EDUCONS, 21208 Sremска Kamenica, Serbia
5Safer Chemicals Alternative-ALHem, Hektoroviceva 1a, 11000 Belgrade Serbia
6ChemExpert, 11000 Belgrade, Serbia
*corresponding author: Jelena Milic; email: jelenamilic@chem.bg.ac.rs

Introduction

Assessing the socio-economic impact change for dangerous chemicals including persistent organic pollutants (POPs) as its specific segment includes analysis of its impacts on human health, environment and local economic development. Those substances have adverse effects to the environment, by making the use of natural resources more difficult and thus have an adverse impact on the ecosystem and causing additional costs to bring it back into balance (Stockholm Convention, 2015). Their impact on economic development is manifested primarily through reduced productivity of society due to the impairment of the health of the population and natural resources (Brnjas et al, 2015).

Impacts which may be subject of the socio-economic assessment and POPs effects assessment are most frequently classified into three basic groups, as follows:
- impact on the health of people,
- impact on the environment and
- impact on the economic development.

All these aspects have been the focus of specific research efforts, but the strongest emphasis is put on the assessment of POPs impact timeline on the health of people (Figure 1).

Results & Discussion

The aim of this socio-economic analysis was quantification of impact of POPs chemicals on human health, specifically on the carcinogenic one and, where it was possible, monetizing these effects and expressing them in financial terms. We have been identified potential effects of 22 POPs on the health, and then we extracted those effects with the most detrimental consequences to the health— namely the carcinogenic effects and other particularly dangerous illnesses (RHIF Serbia, 2015).

The costs related to the treatment of carcinomas diseases (G1 group) in Serbia in the observed period (2011-2015) ranged between approximately 175.9 million euros (2011) and 158.6 million euros (2015). The costs referring to individual cases (treatment of diseases from the stated groups per individual patient) were between rather stable and oscillated around figure of 1.5 thousand euros (Fig 2).

The costs for treatment of non-carcinogenic diseases (G2 group) in the provided period were between 237.3 million (2011) and 260.1 (2015) million euros. The cost of treatment of diseases from this group in given period was between 1.8 thousand to 0.9 thousand euros per patient (Fig 3).

World Health Organization indicates that around 20% of carcinogenic diseases are caused by hazardous chemicals. If we are to begin with a hypothesis that adverse effects of POPs chemicals might comprise at least 10% of the adverse effects of hazardous chemicals (or that they cause approximately 2% of all cases of carcinogenic diseases), we may reach rather approximate estimate of costs required for treatment of the aforementioned diseases caused by POPs in Serbia. The fact that the research of the World Health Organization pertains to the cause of carcinogenic diseases which originate from the work place, could mean that the results are underestimated, considering that it might be expected that the exposure is more intense in the work place than in environment in general.

According to this, the costs of medical treatment of carcinomas which could be connected to POPs in Serbia ranged from 3.5 (2011) to 3.2 (2015) million Euros annually.

Conclusions

Bearing in mind that there are no special data or researches based on which the registered cases of illness could be classified by cause, it is very difficult to provide the amount of stated costs which might be directly linked with POPs. This estimation should primarily be observed as an illustration, which has the main purpose to provide basic idea on the level of these costs rather than to precisely determine real costs of medical treatments of illnesses which may potentially be caused by POPs. According to this, the costs of medical treatment of carcinomas which could be connected to POPs in Serbia ranged from 3.5 (2011) to 3.2 (2015) million Euros annually.

The authors would like to express appreciation for the support of the sponsors Project: Quality Improvement of Master programs in Sustainable Energy and Environment.