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ScienceDirect

Transportation Research Procedia 16 (2016) 355 – 365

Transportation Research Procedia

www.elsevier.com/locate/procedia

2nd International Conference "Green Cities - Green Logistics for Greener Cities", 2-3 March 2016, Szczecin, Poland

Urban air pollution challenge for green logistics

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Abstract

The article attempts to identify green logistics tasks in the area of reducing the negative environmental impacts of households and entities operating in the city. The purpose of this article is to determine changes in relation to the effect of economic entities and households functioning in the city on atmospheric air and waste quantity, as well to indicate cities and agglomerations which are characterized by the greatest degree of hazard in this respect. The analysis looks at the following variables: pollutants emissions in cities at high environmental risk of air pollutants emissions from environmentally harmful facilities, concentration of suspended particulate matter pm10 by agglomerations, concentration of sulphur dioxide, nitrogen dioxide, carbon monoxide and benzene and lead by agglomerations, mixed municipal waste collected and treated in cities, controlled landfill sites in operation by urban areas. Data from the years 2005 and 2013 were analyzed. In the article the methods of descriptive and mathematical statistics were used.

Peer-review under responsibility of the organizing committee of Green Cities 2016.

Keywords: green loistics; urban logistics; air pollution; waste

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Peer-review under responsibility of the organizing committee of Green Cities 2016.
doi:10.1016/j.trpro.2016.11.034

1. Introduction

Processes realized in a city are not without an impact on the environment. Especially transportation and production systems influence the elements of the ecosystem negatively, which is why the search for solutions to environmental problems in city management is virtually as important as realization of economic goals. But as the two objectives are often divergent, it is not an easy task to achieve both. Benefits of pro-environmental activities can be non-measurable, which makes it hard to express them through an outlay-benefit analysis.

Air pollution is one of the environmental problems of cities. It is an especially burdensome factor, because it means harm to people's health as well as deterioration of living conditions. Quality of air is one of the Local Agendas 21 indexes which determined the sustainability of a city at a local level (Marsal-Llacuna, Colomer-Llinàs and Meléndez-Frigola, 2015). Air purification and carbon sequestration are regarded ecosystem services in the context of cities (Rodríguez-Rodríguez, Kain, Haase, Baró and Kaczorowska, 2014). These services are defined as benefits provided by nature (Szarejko and Ładysz, 2014). But for the environment it is only possible to provide services when it is protected. Protection of intrinsic qualities of natural ecosystems is a social need and is understood as an enhancement, retention or reinforcement of the state of ecosystems in terms of internal goals through appropriate resources, infrastructure and institutions (Haan, Ferguson, Adamowicz, Johnstone, Brown and Wong, 2014). In order to be able to provide services, ecosystems require proper maintenance and revitalization, which motivates cities to undertake pro-environmental initiatives.

Realization of urban initiatives for air protection contributes to the development of concepts and solutions branded as carbon-neutral, low-carbon, smart-eco, sustainable, ubiquitous-eco and zero-carbon, emphasised in the context of city development (Yigitcanlar and Lee, 2014). The premise of these concepts is the creation of urban spaces with little to no air pollution emission. Following this comes the need for systemic solutions provided by green logistics which help find such ways of environmental protection, which embrace the totality of flows of all kinds of resources from producer to end user. Green logistics is of particular relevance in a city due to the multitude and variety of goods transportation processes between the places of production and reception. Green logistics revolve around activities connected either directly or indirectly with environmental protection. The former include renewable energy, pollution reduction, noise prevention, waste disposal, the latter - reduction of transportation congestion and development and modernization of urban infrastructure.

2. Green logistics for clean air

Dynamic development of cities necessitates effective solutions to environmental problems which often stem from realization of logistic processes of supply, production and distribution. Currently, the main goal of activities performed through logistics is minimizing negative effects of economic and residential activity of people, including external effects (e.g. congestion, pollution of the environment) while increasing logistic benefits such as cost reduction and customer service improvement (Ambrosino and Sciomachen, 2014). A clean logistics process is becoming the basic element of logistic activities (Kadłubek, 2015). A systemic approach in logistics enables such an organization of activities, which eliminates the clash between the environmental and economic goals.

Green logistics accentuates protection of air. Related research and green supply chains are mostly directed towards economic, environmental and social performance (Subramanian and Gunasekaran, 2015). The concept of green logistics, therefore, favours solutions leading to realization of all goals of sustainable development, not just the environmental ones. Green logistics covers activities oriented towards: logistics environmental management, low-carbon warehousing and packaging, low-carbon transportation, fleet management, alternative energy and logistics innovation (Zhang, Thompson, Bao and Jiang, 2014). Other targets of green logistics refer to external cost reduction with respect to climate change, air pollution, noise, vibration and accidents (Jedliński, 2014).

Transport is one of the main sources of air pollution in a city. Therefore, green logistics should be supported by urban logistics whose strategy is “to efficiently and effectively manage urban freight transport and other traffic flows, with a main objective of achieving an optimal trade-off between ensuring optimum supply network productivity, reliable customer service and reducing environmental impacts, air pollution emissions, energy consumption and traffic congestion” (Amaral and Aghezzaf, 2015). Reduction of air pollution is one of the tasks of a green supply chain (Table 1), which is synonymous with green logistics (Seroka-Stolka, 2015). Managing a green supply chain in the context of air pollution is associated mostly with the emission of carbon dioxide or carbon footprint (Fahimnia, Sarkis and Davarzani, 2015). Paying close attention to the emission of carbon dioxide, also in the context of a city, is caused by the fact that the direct and indirect emission of this gas, which originates from urban consumption, is growing rapidly and is regarded as the main cause of the carbon dioxide level increase generally (Cai and Zhang, 2014; Wang, Zhao, Li, Liu and Liang, 2013). Moreover, it has been proved that the level of carbon dioxide emission depends on the population (Saenz-de-Miera and Rosselló, 2014), which is currently growing in cities. Research into green supply chains shows that (Ghosh and Shah, 2015):

- The main stimulus for taking up green activities comes from green conscious consumer demand and carbon footprint reduction effort.
- Their effective use is dependent on collaboration, and especially joint decision making on green product design, sharing the burden of greening costs, long term supplier commitments.

Hence the reduction of carbon dioxide emission (along with cost and social goals) is crucial in multi-criteria programming of activities realized through green logistics (Rodrigues Pereira Ramos, Gomes and Barbosa-Póvoa, 2014; Pérez, Carrillo and Montoya-Torres, 2015). The functions of transport optimization models in a city are also connected with pollution other than carbon dioxide (Souza, Silva, Silva, D’Agosto and Barboza, 2013).

Table 1. Green supply chains environmental emphasis scenario (Jayaram and Avittathur, 2015).

	Important items	
Question	Low environmental emphasis scenario	High environmental emphasis scenario
Consumption related issues	Educating themselves about environmental issues	Buying more products made from environmentally friendly components
Company level responses	Reducing energy consumption Educating employees about important environmental issues	Pollution prevention by means of approaches such as emissions reduction Capturing environmental information such as energy use and carbon emissions Reporting performance along environmental information such as energy use and carbon emissions
Expected changes to the supply chains	Using recycled packaging materials Recycling process waste back into the manufacturing process	Building products with environmentally friendly materials Designing and developing processes keeping in mind their environmental impact

The task of green logistics is to integrate environmental goals with decision making processes of economic entities, when it comes to moving resources where an individual entity is responsible for proper realization of the procedures connected with resources flow. This means that green logistics undertakes activities which require commitment from all cooperating partners and are directed toward economic and environmental efficiency.

3. Air pollution in cities - causes and solutions

As for air quality in cities, organization of transport is a remarkable problem. Transport processes are the origin of air pollution and waste such as tyres, oil and other materials (Iwan, 2014; Iwan, Kijewska and Kijewski, 2014; Małecki, Iwan and Kijewska, 2014). That is why plans for reduction of transport intensity and emissions are developed. They involve activities such as: usage of reduced-emission trucks, usage of reduced-emission tyres, driver training in order to reach environmentally conscious driving behaviour, consideration of emission values in truck procurement (Large, Kramer and Hartmann, 2013).

Smart environment is the name of activities which can reduce the environmental impact, including air pollution. They are undertaken within the framework of the “smart city” concept and involve technologies such as solar energy and other renewable sources of electricity (Letaifa, 2015), alternative data for household-level heating technologies (Ekholm, Karvosenoja, Tissari, Sokka, Kupiainen, Sippula, Savolahti, Jokiniemi and Savolainen, 2014), and activities for environmental protection and carbon dioxide emission (Zygiaris, 2013; Moriarty and Honnery, 2015). Methods of production and consumption of energy are considered as factors highly influencing the environment in a city. That is why heat provision is increasingly done through solutions like co-generation of heat and electricity in semi-centralized, combined heat-and-power plants and distribution through district heating systems (Späth and Rohracher, 2015). What is more, cities implement the concept of industrial symbiosis which means the exchange of resources between entities in order to protect the environment. An example of that is the use of the surplus of carbon dioxide and steam heat from ammonia production to heat green houses and to grow plants (Paquin, Busch and Tilleman, 2015). Another way of air protection is planning and implementing solutions of green infrastructure in public urban spaces (Rößler, 2015; Kowalski, 2010). Also popular are construction projects which reduce the use of resources in the phase of the actual construction and then throughout the building exploitation, as well as the emission of pollution connected with those activities, e.g. through the use of special equipment (Xue, Zhang, Zhang, Yang and Li, 2015).
Also, the right urban planning with respect to the emission of greenhouse gases is significant. This process should take into consideration factors that influence the level of greenhouse gases emission as well as the relationships between the factors and the emission level. Especially it should (Zubelzu and Álvarez, 2015):

- Determine possible sources of greenhouse gases emissions in the context of urban planning,
- Identify the components of the carbon footprint and determine their significance in order to apply proper prevention methods,
- Investigate relationships between the carbon footprint and design parameters.

Waste and landfilling are another important problem in a city. Landfills generate particulate and gaseous pollution which considerably influences the quality of air. Organizing waste management is no longer merely an obligation, but a challenge for city authorities (Huang and Lin, 2015). The difficulties include the growing area of landfills and inhabitants' reluctance toward starting new ones (Hayami, Nakamura and Nakamura, 2015). The functioning of landfills also generates pollution produced by the equipment used there, e.g. carbon monoxide, nitrogen oxide, hydrocarbons, heavy metals. Another problem connected with landfills is emission of biogases which are prone to self-ignition. These hazards make activities for minimizing the negative influence of waste on air very important. Along the hierarchy of pro-environmental activities, we should aim at avoiding pollution in the first place. Accordingly, the main air protection method with respect to landfills should be reduction of waste quantities and the number of landfills in urban areas.

4. Air pollution in cities in Poland - a statistical analysis

Polish cities also face challenges concerning air pollution. They are expected to act towards improvement of the quality of air. To get a detailed picture of the situation in Poland, an analysis was made in order to find out how the pollution levels changed over the period of a few years. The analysis looks at the following variables:

- EPAR/2013 – particulate emissions in cities at high environmental risk of air pollutants emissions from environmentally harmful facilities in 2013 (thousand tonnes),
- EPAR/2005 – particulate emissions in cities at high environmental risk of air pollutants emissions from environmentally harmful facilities in 2005 (thousand tonnes),
- EGAS/2013 – gaseous pollutants emissions in cities at high environmental risk of air pollutants emissions from environmentally harmful facilities in 2013 (thousand tonnes),
- EGAS/2005 – gaseous pollutants emissions in cities at high environmental risk of air pollutants emissions from environmentally harmful facilities in 2005 (thousand tonnes),

- ESO_2/2013 – sulphur dioxide emissions in cities at high environmental risk of air pollutants emissions from environmentally harmful facilities in 2013 (thousand tonnes),
- ESO_2/2005 – sulphur dioxide emission in cities at high environmental risk of air pollutants emissions from environmentally harmful facilities in 2005 (thousand tonnes),
- ENO_x/2013 – nitrogen oxide emission in cities at high environmental risk of air pollutants emissions from environmentally harmful facilities in 2013 (thousand tonnes),
- ENO_x/2005 – nitrogen oxide emissions in cities at high environmental risk of air pollutants emissions from environmentally harmful facilities in 2005 (thousand tonnes),
- ECO_2/2013 – carbon dioxide emissions in cities at high environmental risk of air pollutants emissions from environmentally harmful facilities in 2013 (thousand tonnes),
- ECO_2/2005 – carbon dioxide emissions in cities at high environmental risk of air pollutants emissions from environmentally harmful facilities in 2005 (thousand tonnes),
- CONP/2013 – value of standardized average annual concentration of suspended particulate matter pm10 by agglomerations in 2013 (μg/m3),
- CONP/2005 – value of standardized average annual concentration of suspended particulate matter pm10 by agglomerations in 2005 (μg/m3),
- $CONSO_2$/2013 – value of standardized average annual concentration of sulphur dioxide by agglomerations in 2013 (μg/m3),
- $CONSO_2$/2005 – value of standardized average annual concentration of sulphur dioxide by agglomerations in 2005 (μg/m3),
- $CONNO_2$/2013 – value of standardized average annual concentration of nitrogen dioxide by agglomerations in 2013 (μg/m3),
- $CONNO_2$/2005 – value of standardized average annual concentration of nitrogen dioxide by agglomerations in 2005 (μg/m3),
- CONCO/2013 – value of standardized average annual concentration of carbon monoxide by agglomerations in 2013 (μg/m3),
- CONCO/2005 – value of standardized average annual concentration of carbon monoxide by agglomerations in 2005 (μg/m3),
- CONBEN/2013 – value of standardized average annual concentration of benzene and lead by agglomerations in 2013 (μg/m3),
- CONBEN /2005 – value of standardized average annual concentration of benzene and lead by agglomerations in 2005 (w μg/m3),
- WAST/2013 – mixed municipal waste collected and treated in cities in 2013 (per capita in kg),
- WAST /2005 – mixed municipal waste collected and treated in cities in 2005 (per capita in kg),
- LAND/2013 – controlled landfill sites in operation by urban areas in 2013 (number),
- LAND /2005 – controlled landfill sites in operation by urban areas in 2005 (number).

The data come from the data base of the Central Statistical Office [GUS Database]. Choosing the variables, objects and years for the analysis is dictated by the data accessibility and the possibility and relevance of examining their relationships. All calculations were performed with the STATISTICA 12 program. Table 2 shows basic descriptive statistics for variables determining the level of pollutants emissions in 126 selected Polish cities at high environmental risk of air pollutants emissions from environmentally harmful facilities.

Table 2. Descriptive statistics for variables determining the level of pollutants emission in selected Polish cities.

Variable	Mean	Minimum	Maximum	Standard deviation	The coefficient of variation
EPAR/2013	0.2444	0.00000	3.50	0.392	160.39%
EGAS/2013	962.2167	64.40000	10238.10	1816.455	188.78%
ESO_2/2013	2.1603	0.00000	25.00	3.967	183.63%
ENO_x/2013	1.3778	0.00000	14.90	2.390	173.46%
ECO_2/2013	954.5206	27.10000	10206.70	1805.900	189.19%
EPAR/2005	0.6540	0.00000	9.00	1.039	158.87%
EGAS/2005	999.5881	66.60000	13377.60	1858.592	185.94%
ESO_2/2005	3.8389	0.00000	50.00	7.425	193.41%
ENO_x/2005	1.6587	0.00000	18.90	2.975	179.36%
ECO_2/2005	990.2413	36.20000	13324.60	1846.871	186.51%

The analyzed variables vary strongly. The variability coefficient is higher than 100% for every feature, which means Polish cities differ significantly in terms of the level of solid and gaseous pollutants emission. What is more, a strong correlation between the emission of individual pollutant types was observed in both discussed years (Table 3).

Table 3. The correlation matrix * for variables determining the level of pollutants emissions in selected Polish cities in 2013 and 2005.

	EPAR/2013	EGAS/2013	ESO_2/2013	ENO_x/2013
EPAR/2013	1.000000	0.618931	0.666045	0.737496
EGAS/2013	0.618931	1.000000	0.933264	0.921398
ESO_2/2013	0.666045	0.933264	1.000000	0.934354
ENO_x/2013	0.737496	0.921398	0.934354	1.000000
	EPAR/2005	EGAS/2005	ESO_2/2005	ENO_x/2005
EPAR/2005	1.000000	0.505833	0.572662	0.517607
EGAS/2005	0.505833	1.000000	0.927540	0.912641
ESO_2/2005	0.572662	0.927540	1.000000	0.951009
ENO_x/2005	0.517607	0.912641	0.951009	1.000000

* All correlation coefficients are statistically significant at a significance level of less than 0.05.

A significant linear correlation between the level of individual pollution types reveals the need for systemic solutions for air protection in cities.

Further analysis was based on a t-Student test for two average values of dependent samples, sign test and the Wilcoxon signed-rank test. The t-Student test is used when two series of results for the same elements are analyzed at different times. For every random sample, the difference between the first and second result is calculated. It is done with an assumption that the distribution of the population is normal. This test verifies the hypothesis about the null average difference between the first and second result in the whole population. The Wilcoxon and sign tests are used to find out about the significance of difference between two dependent samples. They do not require the assumption about the normality of differences distribution. The results are interpreted to verify the hypothesis that both samples belong to the same population. The sign test is based on signs connected with comparing results in pairs. For the measurable data only the signs of differences are considered, not their values. The Wilcoxon rank test for pairs takes into consideration both the signs of the differences and their value and sequence. The differences are organized in an ascending order and then they are given ranks. The ranks for positive and negative differences are summed separately. The smaller of the obtained sums is the Wilcoxon test value which is juxtaposed with the theoretical value from the tables to decide whether or not to reject the null hypothesis.

In order to see if the air protection methods implemented in Polish cities were effective, the analysis compares the average values of individual variables from the years 2013 and 2005. Measurements were done for the same cities with regard to the same element of the population. The results of both groups, therefore, are treated as a result of one sample. The analysis of the differences between the level from 2013 and 2005 was based on the test for the average difference. Two hypotheses were put forth: a null hypothesis about a null difference between the average level of a given pollution type from the year 2013 and the average value from the year 2005, and an alternative hypothesis that the difference between the average levels is different from zero.

The values significantly different from zero were checked for being negative to see if the average pollution level from 2005 is higher than the average from 2013. The verification of the hypothesis about the null difference was done at the 0.05 significance level. The results are shown in Table 4.

Table 4. The t test for interrelated samples for variables determining the level of pollutants emission in selected Polish cities.

A pair of variables	t theoretical value	t critical value (two-sided rejection region)	Test power* (two-sided rejection region)	t critical value (left rejection region)	Test power (left rejection region)
EPAR/2013 - EPAR/2005	-5.26833	1.9791	0.9995	-1.6571	0.9998
EGAS/2013 - EGAS /2005	-0.753177	1.9791	0.1160	-1.6571	0.1852
ESO_2/2013 - ESO_2/2005	-4.92941	1.9791	0.9983	-1.6571	0.9994
ENO_x/2013 - ENO_x/2005	-3.32643	1.9791	0.9101	-1.6571	0.9519
ECO_2/2013 - ECO_2/2005	-0.724047	1.9791	0.1109	-1.6571	0.1776

* The power of the test means the likelihood of avoiding the second type error, i.e. not rejecting a false null hypothesis. In practice, the power of the test which is not lower than 0.8 is accepted as sufficient.

Therefore, we can assume that the average level of particulate emissions in cities at high environmental risk of air pollutants emissions from environmentally harmful facilities was lower in 2013 than in 2005. Unfortunately, it is not the case when it comes to gaseous pollutants emissions in cities at high environmental risk of air pollutants emissions from environmentally harmful facilities, because the average level of this type of pollution in 2013 was very close to the one in 2005. If we look at gaseous pollution individually by type, only the average level of carbon dioxide emissions in 2013 was insignificantly different from that of 2005. The average emission of sulphur dioxide and nitrogen oxide in 2013 was significantly lower than in 2005. For the majority of pollutants there is a significant improvement in the level of emissions, which translates into a better quality of air and, accordingly, quality of life as well.

The sign test and Wilcoxon test yielded slightly different results which are a non-parametric alternative to the t-test for linked variables (Table 5). These tests are used in determining the significance of differences between two interrelated samples.

Table 5. Sign test and Wilcoxon test for variables determining the level of pollutants emission in selected Polish cities.

A pair of variables	Sign test			Wilcoxon test		
	v<V	Z'	p value*	T	Z	p value
EPAR/2013 & EPAR/2005	95.2381	9.17346	0.000000	78.000	8.645772	0.000000
EGAS/2013 & EGAS/2005	65.8730	3.47440	0.000512	2458.500	3.754418	0.000174
ESO_2/2013 & ESO_2/2005	80.0000	6.34103	0.000000	837.000	6.971306	0.000000
ENO_x/2013 & ENO_x/2005	76.1364	4.79702	0.000002	917.000	4.331451	0.000015
ECO_2/2013 & ECO_2/2005	65.8730	3.47440	0.000512	2499.500	3.654592	0.000258

v<V – percent of the number of variables for which the difference is negative, Z' – critical value of sign test, p – p-value for the tests

T – critical value of Wilcoxon test for group size n≤25, Z – critical value of Wilcoxon test for group size n>25

* If the test probability (p-value) is lower than the set significance level, the null hypothesis should be rejected.

In the sign test and Wilcoxon test we reject the distribution equality hypothesis which means that the used methods of air pollution reduction helped the problem of air pollution in Polish cities.

A statistical analysis was also carried out for the variables determining the value of standardized average annual concentration of pollutants in selected agglomerations in Poland. Table 6 presents basic descriptive statistics for these variables. The following agglomerations were discussed: Białystok, Bydgoszcz, Górny Śląsk, Kraków, Lublin, Łódź, Poznań, Rybnik-Jastrząb, Szczecin, Trójmiasto, Warszawa, Wrocław.

Table 6. Descriptive statistics for variables determining the value of standardized average annual concentration of pollutants in selected agglomeration in Poland.

Variable	Mean	Minimum	Maximum	Standard deviation	The coefficient of variation
CONP/2013	34.2500	19.0000	51.100	10.2869	30.03%
$CONSO_2$/2013	7.2667	3.2000	14.700	4.2070	57.89%
$CONNO_2$/2013	25.9667	11.0000	40.100	9.3678	36.08%
CONCO/2013	515.0250	306.3000	896.000	193.3733	37.55%
CONBEN/2013	0.0195	0.0000	0.046	0.0126	64.62%
CONP/2005	38.0500	22.1000	67.500	14.7885	38.87%
$CONSO_2$/2005	13.1500	1.7000	53.000	14.8780	113.14%
$CONNO_2$/2005	26.2250	11.8000	39.100	7.5737	28.88%
CONCO/2005	582.4167	373.0000	1171.000	242.1785	41.58%
CONBEN/2005	1.7161	0.0000	5.405	1.5080	87.87%

The majority of variables in both analyzed years show a moderate diversification level. It is easy to see, though, that the differentiation in 2005 was bigger than in 2013, which means the discussed features differentiated the agglomerations more in 2005 than in 2013. So the used methods for air pollution reduction resulted in a decrease in the differences between agglomerations in this respect. The highest differentiation level in 2013 was observed for the concentration of sulphur dioxide and benzene and lead, and the differentiation was significantly smaller than in 2005.

In order to determine the influence of the used air protection methods on the level of pollution concentration in agglomerations in Poland, a t-test for interrelated samples was done. The results are shown in Table 7.

Table 7. The t-test for interrelated samples for variables determining the value of standardized average annual concentration of pollutants in selected agglomeration in Poland.

A pair of variables	t theoretical value	t critical value (two-sided rejection region)	Test power* (two-sided rejection region)	t critical value (left rejection region)	Test power (left rejection region)
CONP/2013- CONP/2005	-1.6462	2.2010	0.3211	-1.7959	0.4599
$CONSO_2$/2013- $CONSO_2$/2005	-1.3884	2.2010	0.2454	-1.7959	0.3662
$CONNO_2$/2013- $CONNO_2$/2005	-0.1399	2.2010	0.0519	-1.7959	0.0651
CONCO/2013- CONCO/2005	-1.4575	2.2010	0.2655	-1.7959	0.3908
CONBEN/2013- CONBEN/2005	-3.9121	2.2010	0.9445	-1.7959	0.9779

* The power of the test means the likelihood of avoiding the second type error, i.e. not rejecting a false null hypothesis. In practice, the power of the test which is not lower than 0.8 is accepted as sufficient.

The obtained results show that only in the case of standardized average annual concentration of benzene and lead there were significant differences when we compare the years 2013 and 2005. For the other variables the differences were statistically insignificant, which can be a sign of the lack of effects in terms of the concentration levels of individual pollutant types. The results are hardly optimistic and are confirmed by the sign tests and Wilcoxon tests (Table 8).

Table 8. Sign and Wilcoxon tests for variables determining the value of standardized average annual concentration of pollutants in selected agglomeration in Poland.

A pair of variables	Sign test			Wilcoxon test		
	Percent v<V	Z	p value*	T	Z	p value
CONP /2013 & CONP /2005	75.0000	1.443376	0.148915	17.00000	1.725822	0.084380
$CONSO_2$/2013 & $CONSO_2$/2005	75.0000	1.443376	0.148915	19.00000	1.568929	0.116665
$CONNO_2$/2013 & $CONNO_2$/2005	58.3333	0.288675	0.772830	37.50000	0.117670	0.906329
CONCO/2013 & CONCO/2005	75.0000	1.443376	0.148915	17.00000	1.725822	0.084380
CONBEN/2013 & CONBEN/2005	91.6667	2.598076	0.009375	1.00000	2.980965	0.002874

v<V – percent of the number of variables for which the difference is negative, Z' – critical value of sign test, p – p-value for the tests, T – critical value of Wilcoxon test for group size n≤25, Z – critical value of Wilcoxon test for group size n>25

* If the test probability (p-value) is lower than the set significance level, the null hypothesis should be rejected.

The lack of significant differences between the immissions in 2013 and in 2005 is likely connected with the fact that the immissions in the agglomerations were already below the limits in 2005. According to the directive of the European Parliament 2008/50/WE from 21st May 2008 on the quality of air and cleaner air for Europe, in places where the quality of air is good it should be retained or improved if the air quality goals are not achieved. In the light of the above, a pollution concentration level below acceptable limits does not inspire to take actions to lower the level further. The immission of benzene is an exceptional case. Its concentration level is determined with human health in mind. Benzene is an organic compound included in exhaust gases. It is emitted through burning solid and liquid fuels, coke furnaces and non-ferrous metals. Other sources of benzene emissions are petrol stations, asphalt plants, dry-cleaner's facilities, gravure printing houses, various industries: refinery, chemical, steel, tyre and shoe production. It is clear, then, that the danger of emission and immission of benzene is especially high in cities. As the automotive industry and traffic are on the increase, cities take steps to limit it or implement pro-environmental solutions to the organization of urban transportation. Such activities will result in reduced emissions of benzene.
An analysis of the effects of air protection activities was also conducted for variables which determine mixed municipal waste collected and treated in cities as well as controlled landfill sites in operation by urban areas in Poland. It was assumed that waste and landfills are another source of air pollution emissions through dusts and gases originating there. The existence of significant differences between 2013 and 2005 was investigated for these values as well. A t-test was carried out for dependent samples with selected Polish cities (in the case of municipal waste collected and treated in cities) and voivodeships (in the case of controlled landfill sites) as the unit. The major cities of Polish regions represent the volume of landfilled and treated waste, and the whole regions - the functioning controlled landfills. The cities analyzed: Warszawa, Kraków, Wrocław, Łódź, Poznań, Gdańsk, Szczecin, Katowice, Lublin, Bydgoszcz, Gdynia, Białystok, Toruń, Gliwice, Częstochowa, Rzeszów, Sosnowiec, Kielce, Zabrze. The results are shown in Table 9.

Table 9. The t-test for interrelated samples for variables determining mixed municipal waste collected and treated in cities in Poland.

A pair of variables	t theoretical value	t critical value (two-sided rejection region)	Test power* (two-sided rejection region)	t critical value (left rejection region)	Test power (left rejection region)
WAST/2013- WAST /2005	-3.51664	2.1009	0.9137	-1.7341	0.9586

* The power of the test means the likelihood of avoiding the second type error, i.e. not rejecting a false null hypothesis. In practice, the power of the test which is not lower than 0.8 is accepted as sufficient.

The t-test showed that the efforts to reduce the volume of waste yielded expected results. Less and less waste is generated and treated in cities. The results of the sign test and Wilcoxon test paint the same picture (Table 10).

Table 10. Sign and Wilcoxon tests for variables determining mixed municipal waste collected and treated in cities and controlled landfill sites in operation by urban areas in Poland.

A pair of variables	Sign test			Wilcoxon test		
	Percent v<V	Z	p value*	T	Z	p value
WAST /2013 & WAST /2005	78.94737	2.294157	0.021781	17.00000	3.138890	0.001696

v<V – percent of the number of variables for which the difference is negative, Z' – critical value of sign test, p – p-value for the tests, T – critical value of Wilcoxon test for group size n≤25, Z – critical value of Wilcoxon test for group size n>25

* If the test probability (p-value) is lower than the set significance level, the null hypothesis should be rejected.

The change dynamics in the number of landfill sites in operation by urban areas in the 2005-2013 period were analyzed. Also, the number of urban landfills is decreasing. Analyzing the indexes of dynamics, positive trends can be observed on the basis of the average change rate whose value suggests an annual average decrease in the number of urban landfills in all voivodeships.

All of that means that the volume of landfilled and treated waste in Poland is decreasing, and so is the number of landfills. Similar tendencies are observed for the area of urban landfills. We see, then, that the activities aimed at protection of the environment through reduction of waste have brought expected results.

5. Summary

The increase in urban population and economic development leads to more air pollution in cities, which means hazards for health and worse quality of life. For this reason, city authorities should adjust urban economic, residential and transport processes in a way which prevents air pollution. An approach like this is convergent with the concept of green logistics, which is directed toward low emissions, waste reduction and low energy consumption. The main air pollutants in a city are: particulate pollutants and gaseous pollutants, such as sulphur dioxide, nitrogen oxide, carbon dioxide. From the standpoint of air protection, other important problems are: the concentration of air pollutants and the volume of landfilled and treated waste and the number of landfills. Poland has developed and implemented programmes involving the concept of green logistics to improve the quality of air in cities for years. They programmes cover activities aimed at reduction of emission and immission of pollution generated by economic entities and city residents. Polish cities differ much in terms of pollution emissions, which is connected with their level of industrialization, their potential location on a transit route, urban infrastructure including transport infrastructure. But the implemented solutions bring expected results. Every year the emissions of particulate and gaseous pollution, the concentration of air pollution, the volume of landfilled and treated waste and the number of urban landfills decrease. Effectiveness of the implemented measures is the starting point to achieving environmental goals in a city.

References

Marsal-Llacuna, M.L., Colomer-Llinàs, J., Meléndez-Frigola, J., 2015. Lessons in urban monitoring taken from sustainable and livable cities to better address the Smart Cities initiative. Technological Forecasting & Social Change 90, 611 – 622.

Rodríguez-Rodríguez, D., Kain, J.H., Haase, D., Baró, F., Kaczorowska, A., 2014. Urban self-sufficiency through optimised ecosystem service demand. A utopian perspective from European cities. Futures 70, 13 – 23.

Szarejko, M., Ładysz, J., 2014. Podstawy ekonomiczne kształtowania i racjonalnego wykorzystania miejskiego systemu zielonej infrastruktury, in: "Gospodarka przestrzenna. Aktualne aspekty polityki społeczno-gospodarczej i przestrzennej". In: J. Potocki, J. Ładysz (Eds.), Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu 367, Wrocław, 340 – 349.

Haan, F.J., Ferguson, B.C., Adamowicz, R.C., Johnstone, P., Brown, R.R., Wong, T.H.F., 2014. The needs of society: A new understanding of transitions, sustainability and liveability. Technological Forecasting & Social Change 85, 121 – 132.

Yigitcanlar, T., Lee, S.H., 2014. Korean ubiquitous-eco-city: A smart-sustainable urban form or a branding hoax? Technological Forecasting & Social Change 89, 100 – 114.

Ambrosino, D., Sciomachen, A., 2014. Location of mid-range dry ports in multimodal logistic networks. Procedia - Social and Behavioral Sciences 108, 118 – 128.

Kadłubek, M., 2015. Examples of Sustainable Development in the Area of Transport. Procedia Economics and Finance 27, 494 – 500.

Subramanian, N., Gunasekaran, A., 2015. Cleaner supply-chain management practices for twenty-first-century organizational competitiveness: Practice-performance framework and research propositions. International Journal of Production Economics 164, 216 – 233.

Zhang, Y., Thompson, R.G., Bao, X., Jiang, Y., 2014. Analyzing the Promoting Factors for Adopting Green Logistics Practices: A Case Study of Road Freight Industry in Nanjing, China. Procedia - Social and Behavioral Sciences 125, 432 – 444.

Jedliński, M., 2014. The position of green logistics in sustainable development of a smart green city. Procedia - Social and Behavioral Sciences 151, 102 – 111

Amaral, R.R., Aghezzaf , E.-H., 2015. City Logistics and Traffic Management: Modelling the Inner and Outer Urban Transport Flows in a Two-Tiered System. Transportation Research Procedia 6, 297 – 312.

Seroka-Stolka, O., 2014. The development of green logistics for implementation sustainable development strategy in companies. Procedia - Social and Behavioral Sciences 151, 302 – 309.

Fahimnia, B., Sarkis, J., Davarzani, H., 2015. Green supply chain management: A review and bibliometric analysis. International Journal of Production Economics 162, 101 – 114.

Cai, B., Zhang, L., 2014. UrbanCO2 emissions inChina: Spatial boundary and performance comparison. Energy Policy 66, 557 – 567.

Wang, Y., Zhao, H., Li, L., Liu, Z., Liang, S., 2013. Carbon dioxide emission drivers for a typical metropolis using input–output structural decomposition analysis. Energy Policy 58, 312 – 318.

Saenz-de-Miera, O., Rosselló, J., 2014. Modeling tourism impacts on air pollution: The case study of PM10 in Mallorca. Tourism Management 40, 273 – 281.

Ghosh, D., Shah, J., 2015. Supply chain analysis under green sensitive consumer demand and cost sharing contract. International Journal of Production Economics 164, 319 – 329.

Rodrigues Pereira Ramos, T., Gomes, M.I., Barbosa-Póvoa A.P., 2014. Planning a sustainable reverse logistics system: Balancing costs with environmental and social concerns. Omega 48, 60 – 74.

Camargo Pérez, J., Carrillo, M.H., Montoya-Torres, J.R., 2015. Multi-criteria approaches for urban passenger transport systems: a literature review. Annals of Operations Research 226, 69 – 87.

Souza, C.D.R., Silva, S.D., Silva, M.A.V., D'Agosto, M.A., Barboza, A.P., 2013. Inventory of conventional air pollutants emissions from road transportation for the state of Rio de Janeiro. Energy Policy 53, 125 – 135.

Jayaram, J., Avittathur,B., 2015. Green supply chains: A perspective from an emerging economy. International Journal of Production Economics 164, 234 – 244.

Iwan, S., 2014. Adaptative approach to implementing good practices to support environmentally friendly urban freight transport management. Procedia - Social and Behavioral Sciences 151, 70 – 86.

Iwan, S., Kijewska, K., Kijewski, D., 2014. Possibilities of Applying Electrically Powered Vehicles in Urban Freight Transport. Procedia - Social and Behavioral Sciences 151, 87 – 101.

Large, R.O., Kramer, N., Hartmann, R.K., 2013. Procurement of logistics services and sustainable development in Europe: Fields of activity and empirical results. Journal of Purchasing & Supply Management 19, 122 – 133.

Małecki, K, Iwan, S., Kijewska, K., 2014. Influence of Intelligent Transportation Systems on reduction of the environmental negative impact of urban freight transport based on Szczecin ex ample. Procedia - Social and Behavioral Sciences 151, 215 – 229.

Letaifa, S.B., 2015. How to strategize smart cities: Revealing the SMART model. Journal of Business Research 68, 1414 – 1419.

Ekholm, T., Karvosenoja, N., Tissari, J., Sokka, L., Kupiainen, K., Sippula, O., Savolahti, M., Jokiniemi, J., Savolainen, I., 2014. A multi-criteria analysis of climate, health and acidification impacts due to green house gases and air pollution –The case of household-level heating technologies. Energy Policy 74, 499 – 509.

Zygiaris, S., 2013. Smart City Reference Model: Assisting Planners to Conceptualize the Building of Smart City Innovation Ecosystems. Journal of the *Knowledge Economy* 4, 217 – 231.

Moriarty, P., Honnery, D., 2015. Future cities in a warming world. Futures 66, 45 – 53.

Späth, P., Rohracher, H., 2015. Conflicting strategies towards sustainable heating at an urban junction of heat infrastructure and building standards. Energy Policy 78, 273 – 280.

Paquin, R.L., Busch, T., Tilleman, S.G., 2015. Creating Economic and Environmental Value through Industrial Symbiosis. Long Range Planning 48, 95 – 107.

Rößler, S., 2015. Klimawandelgerechte Stadtentwicklung durch grüne Infrastruktur. Raumforschung und Raumordnung 73, 123 – 132.

Kowalski, P., 2010. Zielona infrastruktura w miejskiej przestrzeni publicznej. Czasopismo Techniczne Architektura z. 5, 2-A, 247 – 253.

Xue, X., Zhang, R., Zhang, X., Yang, R.J., Li, H., 2015. Environmental and social challenges for urban subway construction: An empirical study in China. International Journal of Project Management 33, 576 – 588.

Zubelzu, S., Álvarez, R., 2015. Urban planning and industry in Spain: A novel methodology for calculating industrial carbon footprints. Energy Policy 83, 57 – 68.

Hayami, H., Nakamura, M., Nakamura, A.O., 2015. Economic performance and supply chains: The impact of upstream firms' waste output on downstream firms' performance in Japan. International Journal of Production Economics 160, 47 – 65.

GUS Database, available online: www.stat.ov.pl.

Huang, S.-H., Lin, P.-C., 2015. Vehicle routing–scheduling for municipal waste collection system under the "Keep Trash off the Ground" policy. Omega 55, 24 – 37.