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## CHEMISTRY ISSUES IN THE INVESTIGATION OF STUDENTS' ECOLOGICAL AWARENESS

### PROBLEMATYKA CHEMICZNA W BADANIACH ŚWIADOMOŚCI EKOLOGICZNEJ STUDENTÓW

**Abstract:** The development of chemical industry has brought civilization and economic benefits. Nowadays it is hard to imagine the everyday life without chemical products whose usage raises living standards. Unfortunately, the civilization development, where chemistry significantly contributed, caused unfavourable changes in natural environment. In order to stop further environment degradation, different initiatives are being taken up. They also concern activities in favour of chemical threats reduction. Particular role among those activities plays the concept of *green chemistry* which lists in the framework of sustainable development. One of the methods implementation of sustainable development rules is the properly conducted education in formal and non-formal dimensions. Education Decade for Sustainable Development announced by United Nations General Assembly, testifies its importance. The paper brings a closer current model of ecological (environmental) education on different teaching stages. A method of diagnostic survey was used in order to estimate the level of students' ecological awareness. The research is a continuation of our previous works. A survey was chosen as a research technique, and a questionnaire was a research tool. The questionnaire included 22 questions (closed and half-open ones). The research took into consideration only selected elements of ecological awareness. A special attention was paid to estimation of students' knowledge chemical threat aspects and protection of natural environment. Moreover, the paper presents historical outline of chemical industry development and its significance for civilization. The idea of green chemistry and its educational importance was shown as an example aiming at the reduction of chemical threats.

**Keywords:** chemical threats, environmental protection, ecological education, ecological awareness, didactics of chemistry

## Introduction

In the history of chemistry we can distinguish two ways of its development: technical - usability and scientific. Ancient craftsmanship (*eg* metallurgy, pottery or dyeing) is considered to be the beginning of the first one. After a certain practical knowledge has been gathered, a time has come for scientific generalization. On the basis of conducted experiments, fundamental laws were formulated and chemistry was given a character of separate science. For a long time, technical - usability and scientific chemistry were

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developing in an independent manner. In modern times, particularly in XIX century, there has been an approach of these two ways of chemistry development. Scientific achievements in chemistry have led to turbulent growth of chemical industry. Economic needs also contributed to its development in XIX century. Conditions comprising all the aspects of economy, developing communication network, access to proper raw materials and sources of energy influenced dynamic growth of chemical industry. The dynamic of chemical industry progress can be traced on the example of sulphuric acid production. At the end of XVII century its production in the world did not exceed a dozen or so tons. At the beginning of XIX century, total production of sulphuric acid was several hundred tons a year and at the end it increased to 3.2 million tons [1].

Since 1920s, products of chemical industry have been used on a large scale to satisfy social needs. Today, it is hard to imagine economy functioning and everyday life without products coming from chemical industry. According to Nobel Prize winner from 1991, R.R. Ernst, nowadays, chemical industry is the main pillar of human civilization and culture; without chemical industry, human community, in its present and future forms, is unthinkable [2].

Chemistry has contributed to the development of modern civilization. Presently, chemical industry forms one of the most important branches of global economy. Also in the future, progress of technical civilization will be conditioned by chemical products and chemical methods. Unfortunately, chemistry, its industrial processes and provided products have their contribution to natural environment threats. It is important to stress here that chemical threats are not only caused by chemical industry. Common usage of huge amounts of chemical substances constitutes a threat not only to natural environment but also to human health. In extreme cases, it leads to chemical catastrophes and the names of the cities, where there were present, are the symbols of potential threats which accompany modern civilization. A list with chosen world catastrophes, in the last forty years, with the participation of chemical substances has been put in Table 1. At this point a question arises: what should be done to increase chemical safety? Restriction or even resignation of chemical production in order to diminish chemical threats would lead to regression in civilization. The only solution to this problem is to minimize chemical threats with multi directional activities. We can enumerate following activities:

- implementation of clean (sustainable) technologies,
- formation of international programmes [3],
- preparation of legal regulations increasing chemical safety,
- education.

Programme of green chemistry deserves a special attention as far as activities in favour of diminishing chemical threats are concerned. The concept of Green Chemistry was made up in 1991. According to the definition, green chemistry is a formation of products and chemical processes which are reducing or eliminating the usage and production of substances which are hazardous for people's health and natural environment. The programme of green chemistry is based on 12 principles formulated by Anastas and Warner [4]. Putting these principles into practice contributes to minimize chemical threats and particular role is played by five of them: 3, 4, 5, 11 and 12. Educational aspects of green chemistry should also be taken into consideration. Unfortunately, there is a lack of elaborations devoted to these issues (beside some notices indicating the problem) in Polish literature. In other countries, there have been a lot of publications regarding green chemistry

(eg [5, 6]). Popularization of green chemistry intentions can be contributive to the improvement of chemistry negative image among general public.

The realization of green chemistry principles can significantly contribute to sustainable development which is to ensure balance between satisfaction of humankind social-economic needs and requirements of natural environment protection. The condition of effective implementation of sustainable development is proper state of society's ecological awareness. However, increase of ecological awareness state is dependent on properly run education.

Table 1

A list of chosen world catastrophes with the participation of chemical substances in years from 1970 to 2010

Year	Place	Occurance	Results
1974	Flixborough (Great Britain)	release of huge amounts of hot cyclohexane from cracked pipe; the vapour made with air a mixture which caused an explosion	28 fatalities, 36 injured (53 people harmed outside the plant), serious material losses
1976	Seveso (Italy)	explosion of reactor with trichlorophenol	surrounding area contaminated with dioxins and almost 700 inhabitants were harmed
1984	Bhopal (India)	as a result of a breakdown, a release of about 40 tons of methyl isocyanate to the atmosphere in plants belonging to Union Carbide	more than 3800 fatalities, another thousand or more died after some time due to health complications and about one hundred thousand suffered health damage
1986	Basel (Switzerland)	fire at Sandoz chemical storehouse	pollution of Rhine river with phosphorus and mercury compounds (destruction of wildlife within 400 km)
2000	Enschede (Holland)	fire and explosion of fireworks	20 fatalities, more than 550 were injured, huge material losses
2001	Toulouse (France)	series of explosions of ammonium nitrate(V) in storehouse	death of 29 people, more than 1000 injured, serious material losses
2005	Texas City (USA)	explosion and fire at oil refinery	15 fatalities, more than 180 injured
2010	Ajka (Hungary)	release of about 600-700 thousand cubic meters of "red mud" including strongly caustic sludge and iron oxides	9 fatalities and 150 injured, huge environment losses

Own study based on literature data [7-11]

## Education activities in favour of natural environment improvement

In Poland, in the space of last forty years, conceptions of ecological (in broader meaning environmental) education implementation have changed. In formal education, there has still been a problem: separately or together, namely interdisciplinary or multidisciplinary model? In 1980s, a separate subject called *Protection and environment formation* was brought in schools. However, this introduction turned out to be ineffective. The conception of ecological education has been changed by including environmental contents relating to threats and environment protection in curricula of different subjects. In 1999, there has been a reform of polish education system and it resulted in alteration in ecological education management. Since that time, ecological education was performed on two levels. Environmental contents were added to curricula of particular subjects (eg chemistry, as described in papers [12, 13]). Second level was presented by ecological path as one of educational paths. Functioning model of ecological education after 1999 was

illustrated in papers [14, 15]. Starting with school year 2009/2010, according to the Regulation of the Minister of National Education from 23<sup>rd</sup> December, 2008, a new programme reform was introduced. In accordance with the above mentioned reform, educational paths, as well as ecological path, were removed. The most important contents from previous paths were signed in the scope and contents of particular subjects.

Nowadays, there is a tendency of broadening the concept of ecological (environmental) education by promoting education for sustainable development - ESD. The notion of education for sustainable development consists of issues concerning environment, economy and society. On conformity with Education Strategy for Sustainable Development such education is a process lasting the whole life, starting from the early childhood till higher education as well as adults and goes beyond formal education [16].

The importance of education for sustainable development was presented with the acceptance of the United Nations General Assembly in 2002, a resolution establishing Decade of Education for Sustainable Development in years 2005-2014. This international initiative is a challenge of actions to rise the knowledge and abilities of putting into practice principles of harmonious integration of social and economic contents and concern about the environment. Such activities will undoubtedly cause the increase of society's ecological awareness state.

## Research on ecological awareness

The concept of ecological awareness includes elements from domains like natural science, social sciences and humanities what effects that its unequivocal formulation presents some difficulties. In scientific literature, there are a lot of different definitions of ecological awareness whose authors consider it in narrow and wide range. Hull defines ecological awareness in wide range as a form of social awareness which manifests itself both in thinking and experiences of particular people and in functioning social standards of comprehending, experiencing and estimating the biosphere. The elements of ecological awareness can be examined in descriptive-technological sphere (ecological knowledge and imagination) and axiological-normative sphere (system of values and norms of ecological ethics) [17].

In Poland, the investigation of ecological awareness was started up in 1980s and is dedicated to certain community (*eg* professional, social, aged or territorial groups). Relatively numerous representation in scientific literature has the research of ecological awareness among school children. Less publications are devoted to the research of ecological awareness among students. Presented publications from this field refer to small students' population and limit to one or some studies specializations (*eg* [18-20]).

## Materials and research methodology

The aim of the conducted research was to describe students ecological awareness state and to compare it to the results from years: 2008-2009 (test: 440 people) and 2003-2005 (test: 502 people). Research material was based on inquiry data coming from 165 students of following specializations: biotechnology, environmental protection, chemistry and biology. The research was carried out in 2012-2013 among students of Jan Długosz University in Czestochowa. Method of diagnostic survey was used as a research method. An inquiry was taken as a research technique and a questionnaire was a research tool. It

included 22 questions (open and half-open). The questions referred to: chemical aspects of threats and environment protection (questions: 5, 8, 9, 10, 11 and 12), actions in favour of environment improvement (questions: 4, 6, 16, 18 and 19), knowledge of current natural environment state in Poland and its prognosis for the future (questions: 2, 3 and 7), knowledge of concepts relating to natural environment and ecology (questions: 13, 14 and 17), individual attitude of questioned towards environmental problems (questions: 1 and 20) and sources of information about threats to the natural environment (question 21). In the last question (22), the respondents were to estimate ecological awareness state of Poles. This article presents a research which is a continuation to previous works [21-23].

## Research results and analysis

Inquiry questions are given below (results in percentage are in brackets).

1. Are you interested in problems relating to protection of natural environment?  
a. yes (69.7), b. only when it concerns me (21.8), c. rather not (4.9), d. no (3.6), e. others (0).
2. How do you estimate the degree of natural environment pollution in Poland:  
a. high (37.6), b. average (59.4), c. low (0.6) d. I have no opinion on this subject (0.6), e. others (1.8).
3. How do you estimate the degree of environment pollution in Czestochowa:  
a. high (21.8), b. average (67.90,) c. low (2.4), d. I have no opinion on this subject, because I don't live in Czestochowa (7.3), e. others (0.6).
4. Do you think that an average citizen has got an influence on the condition of natural environment:  
a. yes (89.1), b. rather not (4.8), c. no (0.6), d. it is hard to say (5.5), e. others (0).
5. What do you think has the greatest influence on environment pollution in Poland (at most 2 subpoints can be chosen):  
a. chemical compounds used in agriculture (18.2), b. industrial waste (64.8), c. car communication (61.8), d. municipal waste (29.1), e. others (2.4).
6. What kind of power engineering industry in Poland should be developed in the future (at most 2 subpoints can be chosen)?  
a. wind power station (86.7), b. nuclear power plant (22.4), c. hydroelectric power station (54.5) d. coal power station (5.5), e. others (4.2).
7. How do you estimate the condition of environment in Poland, in the future:  
a. it will be much better (2.4), b. it will be better (29.1), c. it will be the same (13.9), d. it will be rather worse (36.4), e. it will be definitely worse (5.5), f. it is hard to say (12.7), g. others (0).
8. The biggest influence on atmosphere pollution has:  
a. carbon dioxide, hydrogen sulphide, hydrogen chloride (15.8), b. carbon dioxide, radon, nitrogen oxides (6.1), c. sulphur dioxide, carbon dioxide, nitrogen oxides (73.9), d. sulphur dioxide, methane, radon (4.2).
9. One siders "acid rain" as all falls (rain, snow, hail) with pH:  
a. below 5.6 (80.6), b. from 5.6 to 7.0 (13.3), c. above 7.0 (3.0), d. there is no such criterion (3.0).
10. It is considered that the main cause of "ozone hole" is:

- a. sulphur dioxide emission to the atmosphere (3.6), b. dustiness and carbon dioxide emission to the atmosphere (9.1), c. freons emission to the atmosphere (83.0), d. sulphur and nitrogen oxides emission to the atmosphere (4.2).
11. The process of ozone decay, which leads to creation of “ozone hole”, can be catalysed by:
- a. chlorine (27.9), b. nitrogen oxides (19.4), c. nitrogen oxides and chlorine (21.2), d. carbon dioxide (31.5).
12. Freons consist of:
- a. carbon, fluorine, chlorine (44.8), b. carbon, ozone, fluorine (26.1), c. carbon, oxygen, neon (5.5), d. carbon, nitrogen, fluorine (23.6).
13. The process of fertilising water body by leading biophile elements is called:
- a. biological destruction (4.2), b. eutrophication (78.2), c. recession (4.2), d. regeneration (13.3).
14. Biodegradation is considered to be:
- a. natural process which consists of chemical substances decay by microorganisms (79.4), b. disappearance of microorganisms activity because of soil pollution (12.1), c. disappearance of existence in water bodies because of its poisoning (1.8), d. disappearance of vital functions (6.7).
15. What do you associate term “healthy food” with:
- a. food sellers’ overuse who want to increase their profits using this kind of method (13.9), b. products coming from “ecological farms” (67.9), c. it is a misunderstanding, since food should be “healthy” (17.6), d. I have not encountered such term (0.6).
16. Please indicate the best way of storage of radioactive waste:
- a. flooding in the oceanic waters (4.2), b. in inactive excavations of old mines (46.7), c. shutting into outer space (31.5), d. creation of sea-bed repositories (17.6).
17. Environment monitoring can be defined as:
- a. system used for the evaluation of people’s health condition (3.0), b. system used for restoration of usage value in degraded environment (0.6), c. system exclusively used for forecasting the changes in the environment (6.7), d. system of continuous control of environment pollution (89.7).
18. What do you think should be done with industrial factory, unfavourable for environment, which is situated in the area with a high rate of unemployment:
- a. close the factory (9.1), b. limit its activity and as a result, decrease the number of employers (33.3), c. continue the activity of the factory (19.4), d. others (38.2).
19. Do you segregate the waste?
- a. yes (47.3), b. no because of the lack of proper containers (47.3) c. no, although proper containers are present because I do not see point in it (2.4), d. I know nothing about this (0.6), e. others (2.4).
20. What do you think is the most unnecessary thing to do from the point of environment preservation (at most 2 subpoints can be chosen):
- a. grass burning during spring and autumn season (28.5), b. sprinkling salt on the roads during winter season (10.3), c. taking municipal waste to the forests (90.3), d. washing cars in the river (40.6), e. illegal clearing for Christmas trees (9.1), f. others (0.6).
21. Which information source about environment threats is considered to be the most important one (at most 2 subpoints can be chosen):

- a. press (16.4), b. television (54.4), c. radio (6.1), d. higher schools (38.8), e. Internet (61.8), f. others (2.4).
22. How do you estimate the level of Polish ecological awareness:  
a. high (2.4), b. average (41.8), c. low (49.7), d. I have no opinion on this subject (5.5), e. others (0.6).

In case of answers results to questions 5, 6, 20 and 21 percentage values do not sum up to 100 because the interviewees were able to choose two variants of answers.

In order to grasp the dynamics of changes of examined elements regarding students' ecological awareness, given empirical results were compared with research results from previous years: 2008-2009 [23] and 2003-2005 [21]. The answer 'yes' to the question *Are you interested in problems relating to protection of natural environment?* was given by 69.7%. In comparison with researches conducted in years 2008-2009 (81.1%) and 2003-2005 (85.1%), it can be observed that interest in issues connected with environment protection is gradually diminishing. Answering the question *Do you think an average citizen has got an influence on the condition of natural environment?*, positive answer was given by 89.1% of respondents (in research from years 2008-2009 and 2003-2005 accordingly 92.0 and 91.2%). Question 7 applied to the forecast about natural environment in Poland in the future. There was a great "spread" of answers to this question. The greatest number of inquired students (36.4%) think that it will rather be worse (in research from years 2008-2009 and 2003-2005 accordingly 22.0 and 20.9%) and 29.1% of questioned students think that it will rather be better (in research from years 2008-2009 and 2003-2005 accordingly 39.3 and 41.0%). The aim of questions 8, 9, 10, 11 and 12 was to estimate the knowledge of chemical aspects of environment threats. Compared with research from previous years, currently questioned students showed worse knowledge of this subject matter. For example, in answer to the question 10 correct answer stated 83.0 to 84.1 and 87.6% in research from years 2008-2009 and 2003-2005. Question (19) referring to waste segregation is nowadays extremely up-to-date since in Poland the rules of waste disposal are being changed. There is a favourable tendency because 47.3% of questioned students declare that they segregate waste and the same number does not do it because of the lack of proper containers. In research from years 2008-2009, 36.8% of respondents admitted that they segregated waste and 54.3% did not do it. Whereas in research from years 2003-2005 these numbers were accordingly 24.3 and 66.1%. The most important sources of information for respondents relating to natural environment threats are (question 21): Internet (61.8%), television (54.4%), higher school (38.8%), press (16.4%) and radio (6.1%). There have been significant changes with reference to previous research. According to the one from years 2008-2009, the order of information sources was following: television, Internet, higher school, press, radio and in years 2003-2005: television, higher school, press, Internet and radio.

## Summary and conclusions

The comparison of research results, which are subject of this research, with results from years 2008-2009 and 2003-2005 leads to a statement that the level of students' awareness is not satisfactory. In order to improve this state, ecological education, as a form of a subject, should be conducted not only for *Environment Protection* specialization but for other specializations as well.

As already mentioned, there is a dependence between educational activities in favour of environment and the level of social ecological awareness. Aristotle words *The roots of education are bitter, but the fruit is sweet* can be referred to environmental education and its "fruit" might be higher level of ecological awareness.

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## PROBLEMATYKA CHEMICZNA W BADANIACH ŚWIADOMOŚCI EKOLOGICZNEJ STUDENTÓW

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**Abstrakt:** Rozwój przemysłu chemicznego przyniósł korzyści cywilizacyjne i ekonomiczne. Dziś trudno wyobrazić sobie życie codzienne bez produktów chemicznych, których wykorzystanie podnosi standard życia. Niestety postęp cywilizacyjny, do którego chemia wniosła istotny wkład, przyczynił się także do niekorzystnych zmian w środowisku naturalnym. Aby zahamować dalszą degradację środowiska, podejmowane są różne inicjatywy. Dotyczy to także działań na rzecz zmniejszenia zagrożeń chemicznych. Szczególne miejsce wśród tych działań zajmuje koncepcja *zielonej chemii*, która wpisuje się w ramy zrównoważonego rozwoju. Jednym ze sposobów wdrażania zasad zrównoważonego rozwoju jest właściwie prowadzona edukacja w wymiarze formalnym i nieformalnym. O ważności edukacji świadczy ogłoszenie przez Zgromadzenie Ogólne ONZ Dekady Edukacji dla Zrównoważonego Rozwoju (UN Decade for Education on Sustainable Development). W pracy przybliżono aktualny model edukacji środowiskowej (ekologicznej) na różnych etapach kształcenia. Aby ocenić stan świadomości ekologicznej studentów, przeprowadzono badania metodą sondażu diagnostycznego. Badania te stanowią kontynuację wcześniejszych prac. Jako technikę badań wykorzystano ankietę, a narzędziem badawczym był kwestionariusz, który zawierał 22 pytania (zamknięte i półotwarte). W badaniach uwzględniono tylko niektóre składniki świadomości ekologicznej, szczególną uwagę poświęcając ocenie znajomości przez studentów chemicznych aspektów zagrożeń i ochrony środowiska naturalnego. Ponadto w pracy przedstawiono rys historyczny rozwoju przemysłu chemicznego i jego znaczenie dla cywilizacji. Jako przykład działań zmierzających do zmniejszenia zagrożeń chemicznych opisano ideę zielonej chemii i jej edukacyjne znaczenie.

**Słowa kluczowe:** zagrożenia chemiczne, ochrona środowiska, edukacja ekologiczna, świadomość ekologiczna, dydaktyka chemii