

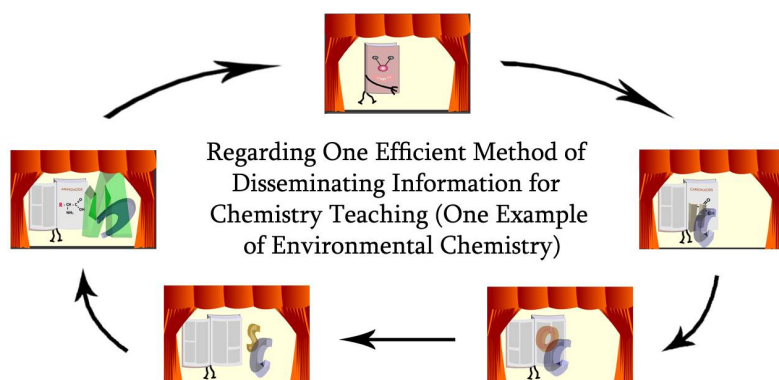
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# Regarding One Efficient Method of Disseminating Information for Chemistry Teaching (One Example of Environmental Chemistry)

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The article deals with methods of chemistry teaching and disseminating chemical information and focuses on the use of art. In particular, the paper describes the method of linking theatre and chemistry and widespread dissemination of chemical information. It cites an example of one specific chemical theatre show “Whirlwind of Elements”, staged by Ilia State University in 2018 and 2019, during an organized scientific picnic. The article specifies the key accents of the play, related to environmental chemistry problematics. The topics discussed are the following: quality of drinking water and water pollution with phthalates and heavy metals, air pollution and smog, acid rain. Very often, people are misinformed about chemical pollution of the environment. Some do not even know and realize that it is their action that causes the pollution. In this respect, the play highlights the human mistakes quite efficiently. It also outlines the semi-structural interview outcomes conducted with teachers, students, and representatives of other professions (non-chemists), randomly selected. The interview confirmed that the chemical emphasis in the play is placed on correct issues, and the connection between chemistry and theater ensures the right result in disseminating the information.

## Graphical abstract



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## 1. Introduction

In 1959, C. P. Snow published “The Two Cultures and the Scientific Revolution”, where he expressed the opinion that art and especially theater were not close to people. However, the

latter was to be used to educate the people. These two cultures are not stand-alone disciplines. Scientists are working to discover the “truth”; Actors even work to present

the truth of life or similarity on stage. However, if we look at history, we will see that theater and science have always been inseparable from each other.

The connection between theater and science has been known from earliest times. For instance, the ancient Greek theatre plays required up to twenty mechanical devices and machines on stage. In Roman theatres, special emphasis was laid on acoustics and architecture. In battle scenes, blood was imitated by a chemical reaction taking place between ammonium thiocyanate and iron (III) chloride. In one of his plays, "the Development of Theater" A. Nicoll wrote that, for entering the gates of the hell, the fire ignited itself by using the chemistry. Unfortunately, he didn't specify which reaction was used, because reactions of "self-igniting" fire are numerous in chemistry [1].

In the epoch of Renaissance, chemistry and science were used side by side. In the theater, they made mechanical decorations and the so-called chemical "tricks". In the nineteenth century, they began to use gases during performances. From this time on, the effect of dry ice dissolving in water was also discovered, but, as the same author noted [1], the proportions were properly defined, meaning that, the release of carbon dioxide was controlled. Later, they began to use electricity to illuminate the stage.

Theater has one unique feature. The actors play, the audience is amused, though in the whole process the spectator learns something. That is, the theatre play literally spreads certain instructions and influences from the play scene. In ancient Greece, it was necessary to reflect religious rituals in performances, and this had an impact on the audience. The viewer saw the mistakes made by main characters, that were followed by terrible consequences, and learned the lesson. Horace, Roman playwright, was convinced that in addition to having fun, the audience had to learn something from the theater.

In this article we will talk about the agitation of the relevant chemistry field such as environmental chemistry with the help of theater.

Recently, environmental chemistry has become increasingly relevant. Therefore, it is especially important to search for and use active methods for its study and dissemination to the masses. There are plenty of methods for active teaching of chemistry [2-5]. However, in this article we will talk about active methods of dissemination information. Dissemination of information to masses is well-timed in relation to environmental chemistry, as a contemporary school student may not choose chemistry as a specialty, or a student may be studying a specialty completely different from chemistry, or he/she may have the knowledge of humanitarian field, although the society needs environmentally educated individuals at all times and at any age. As in most cases, all environmental disasters, chemical pollution of the environment, and diseases conditioned by them are caused by environmentally illiterate people. One of the methods of teaching and disseminating information is the application of popular science articles [4].

No less effective and interesting is to find connection between theatre and chemistry or conduct scientific workshops both for teachers and school students. This article reviews the link between theatre and chemistry [6-11].

### Chemistry on stage

The chemical play was staged by Ilia State University Theatre and was put on show during the scientific picnic in

2018 and 2019. The play was called "Whirlwind of Elements" (Author K. Kupatadze) and referred to contemporary problems of environmental chemistry. Primarily, the performance was intended for young audience, as they represent tomorrow's society and therefore must know today, what ecological problems can be triggered by wrong interference with the nature.

Deriving from the fact that the play was meant for teenagers and afterwards for a wider society, it was planned to be light, informative, and entertaining. Accordingly, we took the story from the realm of fiction. The main characters are twin siblings. The sister is a well-read girl, excellent student. The brother is a bit lazy. They go to an old library, having have to write a project on water. The boy accidentally drops a thick book down from a bookshelf and as a result of oversetting the time, they find themselves in a parallel world of the same library. It happens so that in the library of the other world, there lives a famous traveler - Marko Polo (Fig. 1).

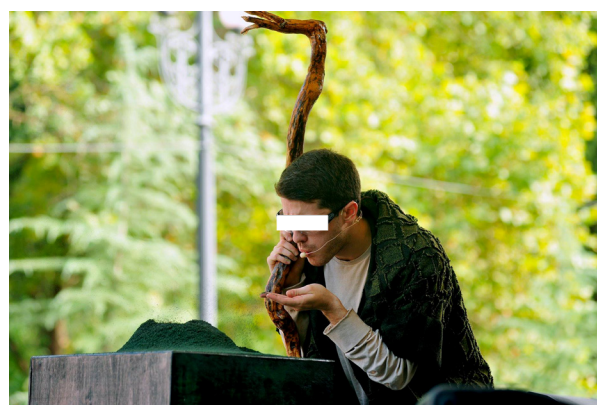


Fig. 1. Famous traveler Marco Polo examines the reaction of ammonium dichromate decomposition.

The purpose of including this historical character in the play is to share historical facts, in addition to chemistry, with teenagers and to find an interdisciplinary connection [12]. Another historical character in the theatre show is a mad hatter, poisoned by mercury. such Hatters used to live in the epoch of the Sun King, Ludovico XIV [13]. For hat painting, they used red dye, produced from mineral Cinnabar, through thermal treatment of HgS [14-16]. For their whole lives, they were under the influence of mercury vapor, therefore, their nervous system and the whole body was affected. By the way, poisoning with harmful substances is talked about many times in the play and it is a kind of warning to the viewer (Fig. 2, 3 and 4).



Fig. 2. Giviko drank water full with phthalates.



Fig. 3. Mad hatter has fun experimenting.



Fig. 4. Mad hatter is showing cinnabar to the audience.

## 2. Results and Discussion

### The style and Language of Chemical Play

*The stage represents a library with some thick books piled on bookshelves. There is a table with some chairs and a table lamp in the room. The door opens and the girl and the boy enter the room. These are the twin brother and sister, Giviko and Tiniko, students in the final year of secondary school, having have to write a topic on water. This is the purpose of their coming to the library. Tiniko is an organized five pointer, while Giviko still lives in childhood, not knowing what to do, what to damage. Giviko is holding a plastic bottle of water in his hand.*

**Tiniko:** - Giviko, please be careful now, do not touch anything unnecessarily, we did not come here for fun.

**Giviko:** - Ok, fine, I know and please, stop telling me what to do as if I were a child. Not to do this, not to touch that (speaking nasally, resentfully).

**Tiniko:** Behave yourself... what plastic bottle are you holding in your hand?

**Giviko:** What, what am I holding? (cannot understand what they want from him)

**Tiniko:** You are holding the bottle that was exposed to sunlight since morning. Now you have taken it and are drinking water from it. Why don't you understand that it is harmful to drink water from a plastic bottle that had been warmed up by the sun?

**Giviko:** And what then? I drank it yesterday, the day before yesterday... what happened to me?

**Tiniko:** Firstly, how can you drink water warmed by the sun in such hot weather and secondly, when the plastic is heated, harmful substances are released in water [17]. So, you are drinking poisoned water. The boy cannot feel anything now! (saying angrily), these harmful substances accumulate in the liver and kidneys and you will feel it in the years to come.

**Giviko:** You might as well know the name of this harmful substance (laughing).

**Tiniko:** Yes, why not. I know, its name is Phthalic and is a product of Phthalic acid. If you listen to the Chemistry teacher, you too will learn many things. Now, let's get to work, we have to write a theme on water cleanliness. I will look at the books on this side, you find something in that corner. Do not take any unnecessary thing, be focused only on water.

Or for instance, in one of the scenarios, there is a talk about mercury poisoning and in this case, we get help from a Mad Hatter.

There is a noise and a "Mad Hatter" bounces into the stage.

**Giviko:** Hey, who are you?

**Marco Polo:** Is that you again? Why can't I get rid of you, why are you wandering in these parallel spaces.

**Hatter:** I am a Hatter, making and painting hats, dying them in red paint (**fidgiting and wheedling**)

**Tiniko:** Why do you have trouble talking? You are faltering.

**Marco Polo:** He is faltering all the time, walking drunkenly and bothering me.

**Hatter:** Somewhere someone told me that I am getting poisoned by mercury, having no idea what it is. I am producing red dye from this stone, it is called "Red Dragon", that's it. **He is taking a reddish-grey stone out of his pocket, showing to everybody.**

I need fire, I will heat it up and then will get dye from it.

**Tiniko:** Grabbing the hatter's hand. No, do not heat it. That is not a stone but a mineral, I've read it in the book. It contains mercury. If heated, mercury will emit in the form of steam and we will all be poisoned.

**Hatter: confused.** I don't know, I always used to heat it and...

**Giviko:** And the consequence is there, Hatter, you can hardly maintain the balance, laughing unreasonably, for sure, you are poisoned.

**Murmuring to himself** – I should give up drinking water from these bottles warmed by the sun.

Neither are the necessary habits forgotten in the play. For example, in one of the scenarios, Marco Polo is talking about the importance of drinking water.

**Marco Polo:** Water... is the blood of the earth... The earth is nourished by it. Clean water is priceless. (**Then he stands up and takes some book, unfolding and reading out loud**), King Philippe II of Spain used to clean water by rose petals [18, 19]... Hm, to be more precise, will clean after two centuries.

**Givi:** How do you know who will do what after two centuries?

**Marco Polo:** As I said, these are magic books, on future. He will clean water - for me, He has already cleaned water - for you and...(critically examining the hatter and then,



**waving the hand down)** I don't know what he will do for this man.

**Giviko:** If the future is written down there, then why did you ask questions about our century, you could have taken this book from the shelf and learned yourself.

**Marco Polo:** No, we don't have the news for such distant times.

**Tiniko:** and then what did he do with that water of rose petals?

**Hatter:** Ha, ha, ha, most probably used to drink and wash.

**Marco Polo: (Looking down in the book)** as it's written here, he used to drink, I don't know.

**Hatter:** How much water should one drink a day?

**Marco Polo:** Two litres a day, as Avicenna prescribed in his medical treatise.

**Tiniko:** It's the same, nowadays, two litres, nothing has been changed.

**Marco Polo:** So, you are guided by Avicenna's book.

**Tiniko: (laughing)** No, not at all. Just drinking two litres of water has not been changed... that's all. Do you happen to know, that the King of Georgia was Vakhtang VI, who wrote a book on chemistry and purified water with marsh plants? Water treatment through wetlands is of relevance even in the 21st century.

The play should mention something about water preservation.

**Tiniko:** Source water can be polluted by harmful substances. It can also be pure. One of the pollutants is Arsenic. In terms of safety, tap water occupies the second place – for the purposes of disinfection, they use to chlorinate tap water.

**Hatter:** What is the tap water?

**Giviko:** Water runs directly in our houses. However, some people do not bother themselves to take care of it and treat water carelessly.

**Hatter:** What do you mean by treating carelessly. Do they throw litter in it?

**Tiniko:** They leave taps running, not taking care and improperly consuming water. They throw some things into it as well, involuntarily contaminating the water. However, there are countries, where water has the price of gold, people are craving for it.

**Hatter:** and what kind of water is this? (pointing at **Giviko's plastic bottle**).

**Tiniko:** Bottled water is the safest. It undergoes special inspection. At least, should do.

**Giviko:** Why do you argue with me telling not to drink?

**Tiniko:** Are you slandering, or what? .... I say not to drink water from sun-warmed bottle.

**Hatter:** Why?

**Giviko:** Yes, once again, explain why!

**Tiniko:** This bottle is made of plastic, sort of material. They add phthalic acid products to make it rigid. When plastic gets heated by the sun, it becomes movable and phthalic diffuses into water. So, you drink water poisoned by phthalic. Is it clear now?

**Hatter:** (hitting his head with his hands). This and that, sometimes mercury, sometimes copper, lead, nickel, arsenic, platinum, chromium ... A whirlwind of elements has covered up everything.

**There comes rain in the final action of the play. Rain is necessary to talk about acid rains:**

**Marco Polo looks from the stage as if looking out of the window.**

**Marco Polo:** Hm, it's raining outside.

**Hatter:** Does it rain in your time too? (**asks the sister and brother**)

**Tiniko:** Yes, it rains more and more often lately. But the rain is acid nowadays.

**Marco Polo:** What, is acid mixed with rain? And what happens if you get wet by rain, will you be burned?

**Tiniko:** No, there is only little quantity of acid. Mr. Polo, do your books read the stories of twentieth century?

**Marco Polo:** No, unfortunately. The narration stops after the nineteenth century.

**Tiniko:** Then, let me tell you one story. In early 70s of the twentieth century, it started raining in one city. So, what happened then, it was a just little rain, wasn't it, that's all. But... ladies' Capron socks became torn. Yea, they melted right in front of their eyes. The rain had increased acid; the Capron of those times was not acid resistant ...

**Hatter:** Hey girl, why are you confusing us, what the hell is Capron.

**Tiniko:** It is a synthetic polymer, can't explain now. Ladies wore socks knitted from Capron fibers and such things happened.

**Giviko:** and how did the acid get in the rain?

**Tiniko:** Givi! Were you asleep at the lesson of chemistry?

**Then she turns to the Hatter and Marco.**

Did you know that the rain water taken from ecologically the cleanest place was of acid nature? [20,21,22] This is thanks to carbon dioxide, formed by infinite coupling and dissolution of two permanent components of the atmosphere, carbon dioxide and water vapor. The reaction is reversible and because of carbonic acid, the rain water is only slightly acidic by nature, however, there are other acidic oxides that lead to acid rains, which are part of the random component in the atmosphere, but are often found in the air.

**Hatter:** Are you speaking about carbon dioxide that I breath out and you freeze?

(In one of the scenes, an experiment was conducted with dry ice and the Hatter recalls and refers to it)

**Tiniko:** Yes, Yes, (**Laughing**);

**Hatter:** You mentioned other components as well. Go ahead, set up a real whirlwind (**making ridiculous grimaces**)

**Tiniko:** They are nitrogen and sulfur oxides. That is, nitrogen and sulfur compounds with oxygen. They rise into the air, accumulate and merge with the existing water, forming the acids. However, this is about our time. Your rain must be less acidic.

**Marco Polo:** It turns out you aren't riding on horseback or mail-cart, right?

**Giviko:** No. Everybody drives vehicles nowadays, whether or not they need to. And most of them are out of order, polluting the air.

**Marco Polo:** Wow, How I would wish to see your time.

**Hatter:** and let the rain be acidic if it does not harm humans, what does it damage?

**Tiniko: (counting on fingers)** 1. It increases acidity of lakes, rivers and reservoirs, affecting the existing flora and fauna and in general, the ecosystem.; Such water becomes useless in every way because the acid environment promotes the release of heavy metal salts from the soil and the water becomes contaminated with heavy metals.

2. It causes forest degradation, most of all it afflicts coniferous plants;

3. Spoils the harvest;

4. Damages the buildings and accelerates rusting process.

**Hatter:** Oh, oh, look at her, she's made up a whirlwind again.

**Marco Polo:** But the air here is especially fresh after the rain.

**Giviko:** Well, Ozone is released, but being unstable, it immediately decomposes into oxygen and we breathe.

The performance lasts for an hour and a half and except for the abovementioned, provides lots of other information as well. Some part of it is historic and some – chemical. For instance, they talk about smog and factors that trigger its formation. Marco Polo recalls his journey to China and Khan of China, who made his people plant trees on the roads, because he knew even at that time that trees clean the air. Lots of fun chemical experiments are being conducted during the show, making its importance even more valuable for promotion of chemistry. For example, experiments on dry ice.

**Hatter:** Look, what is this? (taking dry ice from the shelf, placing his hand on it and shouting out loud), - Oh, it's burning.

**Tiniko:** This is dry ice. Wait! Have you got water anywhere? **(Asking Marco Polo).**

Marco Polo is pointing somewhere at the shelf. Tiniko pours water into the bowl, throwing dry ice into it.

**Hatter** (happy) So good, so good. Is this icy water?

**Tiniko:** No, it's frozen carbon dioxide.

**Hatter:** what's that?

**Giviko: (jumping into discussion with self-confidence)** Hatter, you breath, don't you?

**Hatter:** (pausing to think) I guess so **(Inhaling deeply and then exhaling), Yes, yes, I'm breathing, (laughing happily)**

**Giviko:** So, the thing you exhale, is frozen and that's the dry ice.

**Tiniko:** Good for you, Givi, at least you've learned something about chemistry.

In order to understand teachers' and students' attitude towards such a connection between theatre and chemistry, they were interviewed with the so-called semi-structured interview method. We believed it was the best option, allowing to ask questions in free format. Semi-structured interviews are superbly suited for a number of valuable tasks, particularly when more than a few of the open-ended questions require follow-up queries [23]. Chemistry teachers of both, public and private schools (50 teachers, among them were those, who attended the performance) and students (80), also representatives of completely different professions (20) took part in the interview.

The interview outcomes were expected to show how essential the influence of theatre is in spreading the necessary chemical information and how the plays of similar type will

In total, the play takes an hour and twenty minutes. It is cognitive, both chemically and historically, and keeps the audience amused.

After performance, according to the responses of most teachers, they received new information from the play and are going to use it at chemistry lessons. Most of them think that combining theater and science (in this case, chemistry) is a very effective method of disseminating information. Some, however, think it is effective, but implementation requires a great deal of energy. Most teachers would like to see such performances at school, though they think it will be difficult.

Most students confirm that everything in the play was new to them and that the information they received (by means of fun and unforcedly) will be remembered for a long time. They liked crazy hatter's jokes and chemical experiments in the play. However, some part of the audience liked everything. They are eager to see such performances at school.

People of different professions consider that performances with similar content will raise the cognition in general and provide lots of necessary information. E.g., Most interviewees noted that it was from the play that they learned about harmful effects of phthalates and plastic utensils on human body and about the rules for dealing with such utensils. They also named mercury and generally, the impact of heavy metals on our lives, as another important information

All of them expressed their desire to stage similar performances at their children's schools or would like to take their child to such plays. Also, almost everyone confirmed that they would contemplate on the existing ecological problem in the environment. All interviewees (teachers, students, representatives of other profession) underlined the importance of the language of the play. Complex chemical problem is conveyed in an amusing, simple, understandable language.

This in turn allows everyone to perceive it. E.g., the poisonous properties of mercury are narrated by the "Mad Hatter" in the play. He shows the mineral cinabar to the audience and states, that as they say, there is some kind of metal inside it called mercury and it is very dangerous, because... Or, even one of the twins, named Giviko, falls sick, because he likes to drink water from plastic bottles exposed to the sun and is therefore poisoned with phthalates. He learns this information from his own sister.

Everyone agrees that they themselves will be involved in composing and then staging the play.

### 3. Material and Methods

help teachers in teaching certain topics. Also, how they will assist students in perceiving important chemical information. How easily understandable and applicable in daily life is the chemical information, heard from the stage by those of completely different professions.

In the process of the interview, all the participants were provided with the questions, by our voluntary students. The questions were open and gave the opportunity to freely provide the opinion. Another important issue about the interview was that it was completely anonymous. This, to our opinion, was the guarantee of honest answers. Open questions for teachers and students are provided in the Table 1.

Open-ended questions for teachers and students are given in Table 2.

Respondents' responses were grouped and analyzed according to similarities.

**Table 1.** Questions for teachers and students.

Questions for teachers	Questions for students
<i>Is the connection between theatre and chemistry new to you?</i>	<i>Is the connection between theatre and chemistry new to you?</i>
Did you like the language that conveyed the chemical and environmental issues?	Did you like the language that conveyed the chemical and environmental issues?
Did you receive any new information from the play?	Did you receive any new information from the play?
Will you use the received information (or seen experiments) during the chemistry lesson?	what did you like most in the play (chemical information, historic facts, artists' jokes, chemical experiments, everything)?
Is it justified to disseminate chemical information to general public in this way?	Would you like to see similar plays staged at school?
Will you stage mini plays at school?	Would you take part in writing and then staging a play?

**Table 2.** Did you like the language that conveyed the chemical and environmental issues?

Questions for representatives of other professions
<i>Is the connection between theater and chemistry new to you?</i>
<i>Did you like the language that conveyed the chemical and environmental issues</i>
What was new with regards to environmental chemistry learned from the mentioned play?
Would you like similar performances to be staged at your child's school? would you attend the performance of similar content and why?
Will you consider in life the environmental problems mentioned in the play?

## 4. Conclusions

The presented results of the interview demonstrate that such a method of teaching and spreading chemistry information lead to positive changes in students' and teachers' attitudes. According to opinion research data, the attitude of school students towards chemistry has improved. The outcome is promising, it means that active future works in this direction have chance to be successful.

Ultimately, the survey confirmed that such a connection between theater and chemistry is undoubtedly fruitful. This, of course, will not change people's attitudes towards the environment so quickly, although the changes should start with similar perceptions from school students.

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