CrITERIA

"Cr(VI) Impacted water bodies in the Mediterranean: Transposing management options for Efficient water Resources use through an Interdisciplinary Approach"

WP3, DELIVERABLE 11

Costing of Cr(VI) Contamination Impact for Various Water Uses

ΕΥΡΩΠΑΪΚΗ ΕΝΩΣΗ
ΕΥΡΩΠΑΪΚΟ ΤΑΜΕΙΟ
ΠΕΡΙΦΕΡΕΙΑΚΗΣ ΑΝΑΠΤΥΞΗΣ

Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

Deliverable 11

Costing of Cr(VI) Contamination Impact for Various Water Uses

Athens, March 2020

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1 Introduction

This report aims at evaluating the costing of Cr(VI) contamination impact for various water uses such as civil, agricultural and industrial. More specifically the aim of this task is to determine direct and if possible indirect costs of Cr(VI) contamination. In some of the study areas, where the specific problem is known there might be existing information on actual costs. These will be compiled and assessed against calculated water demands. In areas where data of water Cr(VI) are yet to be evaluated estimates of costing will be based on present cost of water.

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2 Approach regarding costing estimation

As mentioned above, Cr(VI)-contamination costing will be divided in three categories i) the civil cost, ii) the industrial cost and iii) the agricultural cost. The following data will be used for each country that participates in the program in order to estimate the costing effect of Cr-contaminated water.

i. Civil cost

The civil cost, related to drinking and domestic needs, will be determined by using:

- The cost of water per liter at each country,
- The population affected by the contaminated water,
- The average quantity of water consumed per day by person or the annual water consumption at the tested area.

ii. Industrial cost

Two scenarios are tested in order to determine the industrial cost:

Water usage from another source

In this scenario the water consumption by industrial activities and the price of water per liter is required.

Treatment of Cr-contaminated water

In this scenario it is required to know the cost for water treatment per liter of water, taking into account the proposed treatment methods. The methods will be selected based on the level of contamination and the quantity of water that must be treated in order to cover the industrial needs.

iii. Agricultural cost

Two scenarios are tested again. In both scenarios the water demands will be estimated based on the kind of crops at the contaminated area and their water demands taking into account the annual productivity of the contaminated area.

Using water from another source

The water consumption by agricultural activities and the price of water per liter are required.

Treatment of Cr-contaminated water

In this scenario it is required to know the cost for water treatment per liter of water, considering potential treatment methods (details on potential treatment methods with associated costs are analysed in Deliverable of WP4 of CRITERIA project). The methods will be selected based on the level of contamination and the quantity of water that must be treated in order to cover the agricultural needs.

For each country, in order to calculate the contaminated area we have to assume the worst case scenario that at least one sampling point exhibited Cr(VI) concentration above the legislation limit of 50 μg/L.

3 Estimation of Cr(VI)-contamination costing at the CrITERIA participating countries

3.1 The case of Greece

The tested areas in Greece are the Municipality of Loutraki-Perachora, Municipality of Messapia, Municipality of Oinofyta and Municipality of Thiva and their neighboring areas.

3.1.1 Civil cost

The total population of the Municipalities of Oinofyta and Thiva, which are located at the Viotikos Kifissos and Assopos River basins, is 43,000 (census 2011). The annual total drinking water needs are 23 million cubic meters. In some areas in these River basins Cr(VI) concentrations above the concentration limit of 50 ppb have been detected. A part of the 23 million cubic meters can be used as abstraction of groundwater which is calculated at about 3 million cubic meters. Regarding the civil consumption of water the average quantity of water consumed per day by person is about 150 liters/day/person. The government delivers water at the cost of 0.35 euros per cubic meter meaning 0.00035 euros per liter. Assuming that the 3 million cubic meters of water that are attributed to groundwater will not be used, the total cost of this water is calculated at 1.05 million euros [1-3].

Regarding the area of the Municipality of Loutraki-Perachora which belongs to the wider Attica River Basin, total population is estimated to be 16,578 people (census 2011). The total annual drinking water demands in the Attica River Basin are 416 million cubic meters. However, only a very little amount of this is attributed to the tested area which is estimated at about 2 million cubic meters. Taking into account that the drinking water needs at the area are covered by

groundwater sources and Cr(VI) concentrations above the 50 ppb have been detected the cost for clear water will be 0.7 million euros if used from another source with clean water [1-3].

Finally, for the wider area of Municipality of Messapia which belongs to Euboea River Basin the total population is estimated to 13,327 people (census 2011). The total annual drinking water demands at the Euboea River Basin are 27.5 million cubic meters. In some areas in these River basins Cr(VI) concentrations above the concentration limit of 50 ppb have been detected. The average annual abstractions for drinking purposes in the groundwater body of Politika-Psachna are about 2 million cubic meters. The government delivers water at the cost of 0.35 euros per cubic meter and by assuming that these 2 million cubic meters of groundwater will not be used the total cost for using water from clear sources is calculated at 0.7 million euros [1-3].

3.1.2 Industrial cost

Regarding the industrial demands for water, 4.4 million cubic meters per annum are required for industrial activities at the tested areas. More specifically, 1 million cubic meters as annual abstractions are used in groundwater body of Politika-Psachna (Municipality of Messapia, Central Euboea), 3 million cubic meters as annual abstractions in groundwater body of Thiva-Assopos-Schimatari (Municipalities of Oinofyta and Thiva, Asopos river basin) and 0.4 million cubic meters as annual abstractions in groundwater body of West Geraneia (Municipality of Loutraki-Perachora). In these areas Cr(VI) concentrations above the limit of 50 ppb have been detected [1,2].

A. Using water from another source

In the case at which the volume of contaminated groundwater will be replaced with clean water transferred from other sources in order to cover the industrial needs the total cost could be estimated by multiplying the price of water for industrial use with its price. The price of water for industrial use is 0.82 – 0.98 euros per cubic meter depending on the monthly water consumption. Using a median price of 0.9 euros per cubic meter, the total cost regarding the use of the tested areas is about 4 million euros annually [3].

B. Treatment of Cr-contaminated water

In case that the Cr(VI) contaminated water will be treated in order to be used exclusively for industrial needs the cost for its treatment ranges from 0.26 to 0.38 euros per cubic meter. Taking into account that the annual water demand is 4.4 million cubic meters the minimum cost for water treatment is 1.14 million euros annually.

3.1.3 Agricultural cost

Regarding the agricultural demands for water, 57.2 million cubic meters per annum are required for agricultural activities at the tested areas. More specifically, 8.9 million cubic meters as annual abstractions are used in groundwater body of Politika-Psachna (Municipality of Messapia, Central Euboea), 47.9 million cubic meters as annual abstractions in groundwater body of Thiva-Assopos-Schimatari (Municipalities of Oinofyta and Thiva, Asopos river basin) and 0.5 million cubic meters as annual abstractions in groundwater body of West Geraneia (Municipality of Loutraki-

Perachora). In these areas Cr(VI) concentrations above the limit of 50 ppb have been detected [1,2].

A. Using water from another source

In the case at which the volume of contaminated groundwater will be replaced with clean water transferred from other sources in order to cover the agricultural needs the total cost could be estimated by multiplying the price of water for agricultural use with its price. The price of water for agricultural use is 0.18 – 0.30 euros per cubic meter depending on the annual water consumption. Using a median price of 0.24 euros per cubic meter, the total cost regarding the use of the tested areas is about 13.7 million euros annually [3,4].

B. Treatment of Cr-contaminated water

In case that the Cr(VI) contaminated water will be treated in order to be used exclusively for agricultural needs the cost for its treatment ranges from 0.26 to 0.38 euros per cubic meter. Taking into account that the annual water demand is 57.2 million cubic meters the minimum cost for water treatment is 14.87 million euros annually.

3.2 The case of Cyprus

3.2.1 Civil cost

The total population of Cyprus is about 850,000 people and the annual total drinking water needs are 120 million cubic meters, while 110 million of them are household needs. In the case of Cyprus no Cr(VI) contaminated water has been detected to affect populated areas. Regarding the civil consumption of water the average quantity of water consumed per day by person is equal to 120-150 liters/day/person. The government delivers water to the water boards at the cost of 0.82 euros per cubic meter meaning 0.00082 euros per liter.

3.2.2 Industrial cost

Regarding the industrial needs for water, 10 million cubic meters per annum are required for industrial activities. However, till now no Cr(VI) contaminated water has been observed in the Cyprian industrial areas. Below there are some data regarding the cost of water in case of contamination in a specific area.

A. Using water from another source

In case of contaminated water in the specific industrial area the scenario of transporting clear water from another source is feasible since little distances occur between the industrial areas which generally are not far away from household establishments. The price of water for industrial use is 0.25 euros per cubic meter, meaning 0.00025 euros per liter [5].

B. Treatment of Cr-contaminated water

In case of Cr(VI) contamination and assuming water treatment for reuse, the cost is about 0.42 euros per cubic meter [5].

3.2.3 Agricultural cost

In Cyprus the amount of water used for irrigation/agricultural needs is about 155 million cubic meters per annum. No Cr-contamination in agricultural water has been observed in Cyprus. In case of water contamination at an area the following data are available.

A. Using water from another source

In case that there is a need for water usage from another area the cost of irrigation water in Cyprus is 0.17 euros per cubic meter [5].

B. Treatment of Cr-contaminated water

The median cost for treatment of wastewater is 0.07 euros per cubic meter [5].

3.3 The case of Italy

The seven municipalities in the study area are located in the south-west area of the Basilicata region within the Parco Nazionale del Pollino.

3.3.1 Civil cost

Total population in each of them amounts to few thousands, and a total population of about 21,500 inhabitants is estimated for the year 2032 for the whole area. Currently, an average flow of 68,93 l/s is supplied in the area, that is expected to increase up to 92,75 l/s by 2032, that is 2.9 Mm^3/y [6]. The Acquedotto Lucano S.p.A delivers water to civil population at a basic cost of 0,86 €/m^3. This cost is increased on the basis of the actual consumption up to 2,11 €/m^3 [7].

3.3.2 Industrial cost

A total of 3.5 Mm^3/y of industrial water has been estimated to be required in the area for the industrial activities, though limited to small enterprises active in the manufacturing sector. The water is nowadays supplied by Acquedotto Lucano S.p.A. from external sources at a cost ranging from 0,98 €/m^3 to 1,90 €/m^3 according to the actual annual consumption [7].

A. Using water from another source

The use of internal sources is restricted by regulation, since the investigated area is included in a protected area (National Park). An estimation of the cost of supplying water from internal source is therefore not possible.

B. Treatment of Cr-contaminated water

In case that the Cr(VI) contaminated water is treated in order to be used exclusively for industrial needs, the cost of water is expected to increase of about 0.10 euros per cubic meter.

3.3.3 Agricultural cost

A total amount of 0.256 Mm^3/y of water is consumed for agricultural purpose in the area in the year 2018 [8].

A. Using water from another source

The water is nowadays supplied by Acquedotto Lucano S.p.A. from external sources. The cost of irrigation water in the Pollino area is 0.82 €/m^3 euros per cubic meter [7].

B. Treatment of Cr-contaminated water

The median cost for treatment of the contaminated water is 0.10 euros per cubic meter.

3.4 The case of Jordan

Physicochemical analysis of water samples in Zarqa river basin of Jordan did not show any Cr(VI) contamination of water.

3.4.1 Civil cost

The total population of Zarqa governorate is about 1.5 million and the annual total drinking water needs are 73.5 million cubic meters. In the case of Zarqa governorate no Cr(VI) contaminated water has been detected to affect populated areas. Regarding the civil consumption of water the average quantity of water consumed per day by person is about 140 liters/day/person. The government delivers water to the water boards with cost ranging from 0.2 to 2.5 euros per cubic meter depending on the consumption.

3.4.2 Industrial cost

Regarding the industrial needs for water, 35 million cubic meters per annum are required for industrial activities. However, till now no Cr(VI) contaminated water has been observed in the Zarqa's industrial center at which over 50% of Jordanian factories are located. Several facilities such as Jordan's only oil refinery plant are based in Zarqa. According to the Zarqa Chamber of Commerce, 10% of Jordan's total exports in 2011 came from Zarqa Governorate, amounting to more than US $512 million. Leather and garment products constituted about 52% of Zarqa's exports, followed by chemical, agricultural and pharmaceutical products. More specifically, nowadays some industries were moved from the Zarqa River Basin to an area which does not pose any environmental hazards. Thus, the Cr(VI) concentration detected in the Zarqa River Basin is below the Jordanian regulation limits while for the rest of industries remain in the Zarqa River Basin in site treatment plants of industrial waste water have been established under the control of Jordanian government. The government delivers water for industrial use at the cost of 2.5 euros per cubic meter.

3.4.3 Agricultural cost

In Jordan the amount of water used for irrigation/agricultural needs is about 540 million cubic meters per annum. The government delivers water for agricultural use at the cost ranging from 0.3 to 0.5 euros per cubic meter. No Cr-contamination in agricultural water has been observed in Zarqa, Jordan. In case of water contamination at an area the following data are available.

3.5 The case of Turkey

3.5.1 Civil cost

The two areas under investigation in Turkey are Mersin and Tarsus and their population is about 1.2 million and the annual total drinking water needs are about 49 million cubic meters. In these areas no Cr(VI) contaminated water has been detected to affect populated areas. Regarding the civil consumption of water the average quantity of water consumed per day by person is about 90 liters/day/person. The government delivers water to the water boards at the cost of 0.69 euros per cubic meter [9,10,11].

3.5.2 Industrial cost

Regarding the industrial needs for water, 19.5 million cubic meters per annum are required for industrial activities. However, till now no Cr(VI) contaminated water has been observed in the Turkish industrial areas tested [9,10].

3.5.3 Agricultural cost

In Turkey the amount of water used for irrigation/agricultural needs is about 245 million cubic meters per annum. No Cr-contamination in agricultural water has been observed in the tested areas. In case of water contamination at an area the following data are available [9,10].

4 Comparison of alternatives and measures

According to the aforementioned data two cases are observed. The areas at which no Cr(VI) contamination occur and those at which Cr(VI) contamination is detected. In the first case, continuous groundwater monitoring is considered as a necessary action in order to determine possible contamination due to either the presence of ophiolitic rocks or due to agricultural/ industrial activities able to enhance Cr(VI) contamination. Even in the case that Cr(VI) concentration may be observed in groundwater, the management approach will be very different compared to cases that contamination is attributed exclusively to anthropogenic activities. In the case of geogenic origin applying mainly institutional measures, like providing alternative water supply that is free of Cr(VI), is the only reasonable alternative for ensuring safe water within the allowable concentration limits. Only in some cases, ex situ treatment mainly for irrigational needs locally might be also applied [12].

In the second case, at which Cr(VI) contamination is detected as a result of anthropogenic activities like industrial activities, several treatment techniques in situ or ex situ can be applied depending on a) their effectiveness taking into account parameters such as the physicochemical characteristics of groundwater, the Cr(VI) concentration, the volumes that must be treated, b) their cost, c) their complexity, d) their maintainability etc. More details regarding decontamination techniques are provided in Deliverable of WP4.1 of CrITERIA: "Compilation of available Cr(VI) treatment techniques".

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