ORIGINAL PAPER

ASSOCIATED HEALTH RISKS FROM HEAVY METAL-LADEN INFLUENT/EFFLUENT FROM WASTEWATER TREATMENT PLANT

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Abstract. *The wastewater treatment process significantly decreases the negative impact of the effluent on human health compared to the influent. This probabilistic study, based on mathematical formulas, which does not involve clinical studies, investigates the impact of polluting chemical elements on health, which may be higher or lower, depending on other direct or indirect factors. The conclusions from this study were (1) wastewater (the effluent, which falls within legal limits) cannot be used for domestic consumption, much less as drinking water; (2) regarding dermal absorption, this can only be possible if people use the wastewater (influent/effluent) for recreational purposes (bathing, fishing, etc.). If this were theoretically possible, the risks related to the respective water matrices can be much higher because in this study only five heavy metals (Cd, Pb, Cu, Ni, and Zn) found in the international legislation in the categories of substances with carcinogenic risk, were investigated in the wastewater, and it may also contain other substances with different risk degrees. In the future studies will be investigated the health risk assessment gradient related to the effluent from the point of discharge of the wastewater on the flow of the natural receiver.*

Keywords: *wastewater; heavy metals; health risk; carcinogenic risk.*

1. INTRODUCTION

Wastewater is a complex matrix in terms of toxicology. Risk factors are various: biological (bacteria, viruses, parasites), chemical (organic and inorganic pollutants), and physical (radioactive isotopes) as well. Wastewaters are the result of anthropogenic activities, are loaded with various compounds, which must be removed before discharge into a natural receiver (river, lake, sea). Household wastewater, compared to industrial wastewater, is

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generally easier to treat by purification process, due to a predominant content of organic matter and the more diluted degree of various dissolved substances or suspended matter [1, 2]. For their purification, approximately the same technological steps of wastewater treatment can be used regardless of the geographical area [1]. On the other hand, heavy metals (sometimes in high concentrations) are generally characteristic of industrial wastewater. As the matrix of industrial wastewater differs from one type of industry to another, it is clear that their composition is distinct in terms of heavy metal content. The removal of heavy metals from wastewater, when their concentrations in the wastewater are very low, is carried out by conventional methods, but when their concentrations are very high, additional treatment steps are used [3]. As abovementioned, household wastewater does not contain heavy metals in high concentrations, but the legislation requires economic agents to treat their hazardous waste, heavily loaded industrial wastewater being processed by pretreatment methods before discharge into the sewer. In addition, the pretreatment processes are different depending on the type of industrial wastewater. Usually, heavy metals are removed by pretreatment practices, such as chemical precipitation methods [4, 5]. However, pretreated industrial wastewater may contain residual concentrations of heavy metals, and then other measures must be applied to these wastewaters in order to be safe for human health [4-8].

Innovation in the field of wastewater treatment (WWT) must constantly guarantee the safety of discharged water; at the same time contributes to the improvement of the environment-health relationship on scientific bases and to the conservation of biodiversity and the sustainable development of the industrial sector [9-12]. In addition, it is well known that the European Union wanted to find innovative solutions/resources, through the transition to a low-carbon, energy-efficient, and climate-resilient economy, with the aim of improving the quality of the environment and life.

Starting once again from these important assumptions, namely that polluting chemical elements represent a worldwide problem for the environment and health, especially those from wastewater (both influent and effuent), this study is the third part of a series of extensive investigations achieved by authors in terms of heavy metals (*i.e.*, Cd, Pb, Cu, Ni, and Zn) risk on human health. In this respect, a theoretical health risk assessment was performed using calculation coefficients to mathematically demonstrate the direct hazard of the influent *vs.* effluent, in terms of toxic metals content. Mohammadi et al., (2019) revealed that, through the treatment process, the concentration of heavy metals in the influent is reduced and the danger to health is diminished but still must take into account the direct or indirect factors in sustaining the hypotheses and data [13]. In their previous studies, by monitoring the quality of wastewater in terms of heavy metals content at Targoviste Wastewater Treatment Plant (WWTP), in both influent and effluent, the authors [12] highlighted that the variation of chemical elements concentration depends on a series of factors such as chemical, physicochemical, biological, industrial, natural, seasonal, etc.. According to studies of Mohammadi et al., (2019) [13], Chilian et al. (2022) [12], reported that the pH of the influent 7.96 ± 0.10 in "*more active*" form are Pb and Cd, which settle at a higher pH than Ni, Cu, Zn. The highest reduction yield in the wastewater treatment process was found for Cd (73.97 %) and Pb (53.90 %) [12].

This research, based on probabilistic approaches, studied the potential impact on human health of the chemical load of influent and effluent from WWTP of Târgoviște upon theoretical ingestion and dermal absorption. Regarding dermal absorption, this can only be possible if the investigated subjects (*i.e.*, adults and children) use the wastewater (*i.e.*, effluent) as water for body hygiene or for other recreational activities; the risks related to the use of respective water matrices are highest [13]. The health risk assessment gradient decreases from the wastewater discharge point and is directly dependent on the flow of the natural receptor [14-16]. In this respect, the WWTP of Targoviste, Romania, has the outlet of the treated wastewater into the natural receiver (*i.e.*, Ialomita River) at the exit of the river from the perimeter of the city, to minimize the possible impact on health for recreational purposes [17, 18].

2. MATERIALS AND METHODS

2.1. PROBABILISTIC HEALTH RISK ASSESSMENT OF HEAVY METALS IN INFLUENT AND EFFLUENT, RESPECTIVELY

To evaluate the heavy metals (*i.e.*, Cd, Pb, Cu, Ni, and Zn) exposure through both ingestion and dermal absorption of contaminated influent and effluent from urban WWTP, the risk assessment was performed based on chronic daily intake (CDI), hazard quotient (HQ), and carcinogenic risk (CR) parameters according to the prescribed guidelines/studies in the field of environment protection.

2.1.1. Chronic Daily Intake

The chronic daily intake (CDI) is one of the most significant indicators and generally is estimated based on exposure analysis through heavy metals and is used to quantify the risks of both noncancer and cancer health effects [19-24]. The equation (1.1) was proposed by the United States Environmental Protection Agency (USEPA) [26] and taken over in other studies with slight modifications [13, 26]:

$$CDI_{ingestion} = \frac{C_{Me} \times IR \times EF \times ED}{MT \times BW} \tag{1.1}$$

where $CDI_{ingestion}$ is the estimated chronic daily intake of metals (mg/kg/day); C_{Me}, mean metal concentration (mg/L); *IR* is the water daily intake (L/day); *EF* is the exposion freqvency (days/year); *ED* is the exposure period (years); *MT* is the average human lifetime exposure time (days); *BW* is the average body weight (kg).

The CDI_{derm} determination was achieved according to a complex equation (1.2) proposed by Custodio et al. (2020) [27]:

$$CDI_{derm} = \frac{C_{Me} \times SA \times KP \times ET \times EF \times ED \times CF}{BW \times MT} \tag{1.2}$$

where CDI_{derm} is the daily dose of metal absorbed through the skin (mg/kg/day); *SA* is the surface of skin (cm^2); *KP* is the skin permeability coefficient of each metal (cm/h); *ET* is the exposure time (hours/day); *EF* is the exposure frequency (days/year); *ED* is the exposure time (years); *CF* is the conversion factor (0.001 L/cm^3).

2.1.2. Risk Assessment

The risk assessment (*i.e.*, non-carcinogenic and carcinogenic) by both ingestion and dermal absorbtion, has been considered a valuable tool for highlighting the health risk effects for adults and children as well as for providing risk evidence for decision-making [28-32].

Non-Carcinogenic Risk

Another step in determining the health impact of heavy metals in water based on their concentration is to determine the hazard quotient (HQ), which has been recognized as a useful non-carcinogenic parameter for the evaluation of risks associated with humans' exposure, by ingestion and dermal absorption. In case of ingestion, the hazard quotient is noted with $HQ_{ingestion}$. The $HQ_{ingestion}$ is given by equation (1.3) [13, 25]:

$$HQ_{ingestion} = \frac{CDI_{ingestion}}{RfD} \tag{1.3}$$

where $HQ_{ingestion}$ is the hazard quotient of ingestion (unitless); $CDI_{ingestion}$ is the chronic daily intake of metals (mg/kg/day); *RfD* is the reference dose (mg/kg/day) for ingestiom pathway (Table 1).

The values of reference dose RfD and cancer slope factor (SF) for two pathways and five investigated metals are presented in Table 1 [25].

Table 1. Reference dose (RfD), and cancer slope factor (SF) for oral ingestion and dermal pathways in the wastewater of Cd, Pb, Cu, Ni, and Zn

Element	RfD (ingestion) [mg/kg/day]	RfD (dermal) [mg/kg/day]	SF [kg/day/mg]
Cd	0.5	0.005	6.1
Pb	1.4	0.42	8.5
Cu	40	12	NA
Ni	20	5.4	0.84
Zn	300	60	NA

NA - not available; USEPA [26].

In case of dermal absorption, the hazard quotient, HQ_{derm}, is determined by equation (1.4) [13, 25]:

$$HQ_{derm} = \frac{CDI_{derm}}{RfD} \tag{1.4}$$

where HQ_{derm} is the hazard quotient of dermal absorption (unitless); CDI_{derm} is the chronic daily metal absorbed through the skin (mg/kg/day); *RfD* is the reference dose (mg/ kg/day) for dermal pathway (Table 1).

By summating both hazard quotients $HQ_{ingestion}$ and HQ_{derm} was obtained the hazard quotient of metal HQ_{Me} according to equation (1.5) [26]:

$$HQ_{Me} = HQ_{ingestion} + HQ_{derm} \tag{1.5}$$

Hazard Index (HI) for multiple heavy metals. The sum of all HQs gives an estimation of total potential health risks or HI. The total hazard index (HI) is given by equation (1.6) and is expessed by the global impact of several individual hazard quotients (in this case, $HQ_{ingestion}$) [25, 34]

$$HI = \sum_{1}^{\infty} HQ_n \tag{1.6}$$

HI values less than or equal to 1 indicates that the exposure is not likely to result in adverse non-carcinogenic effects; the values greater than 1, however, does not necessarily suggest a likelihood of adverse health effects but still potentially caused risk [34, 35].

Carcinogenic Risk

Another important indicator for the impact of metals on health is related to possible carcinogenic effects. Carcinogenic risk was estimated as the incremental probability of developing cancer during a lifetime due to exposure to a potential carcinogen [36-39]. The carcinogenic risk is calculated according to equation (1.7) [40]:

$$CR_{ing} = CDI_{ingestion} / SF_{ing} \tag{1.7}$$

where $CR_{ing}$is the carcinogenic risk (unitless); $CDI_{ingestion}$ is the estimated chronic daily intake of metals (mg/kg/day); SF_{ing} is the slope cancer factor (mg/kg/day). According to the United States Environmental Protection Agency (USEPA) [25], the acceptable safe risk ranges from 10^{-6} to 10^{-4}.

3. RESULTS AND DISCUSSION

The health risk assessment of the influent and effluent of the Targoviste (Dambovita County, Romania) Wastewater Treatment Plant are investigated on the base of the previous results already published by Chilian et al. (2022) [12]. The wastewater plant was designed for a maximum flowrate of 38.386 m^3/day serving an equivalent population of 125.800 PE and assured preliminary, primary, advanced biological, and sludge treatment up to 25% solids content [1, 4, 5, 12].

The probabilistic analysis was made in two steps: *firstly* are determined the chronic daily intake, for two pathways, ingestion and dermal absorption; *secondly*, are assessed the non-carcinogenic and carcinogenic risk due to ingestion and dermal absorbtion, respectively.

The chronic daily intake (CDI) was determined by using the heavy metal concentrations from the influent and effluent samples of Târgoviște WWTP reported by Chilian et al (2022) [12] with the input parameters presented in Table 2.

Table 2. Parameters and input assumptions for exposure assessment of metals through ingestion pathway.

Parameter	Unit	Values	
		Adult	Children
Daily volume of water ingested	L/day	2.2	1.8
Frequency of exposure	days/year	365	365
Duration of exposure	years	70	6
Average human lifetime exposure time	days	25550	2190
Average body weight	kg	70	15

Fig. 1 shown that for adults the CDI from the influent is the highest for lead (0.005 mg/kg/day), followed by cadmium (0.003 mg/kg/day). The lowest value for CDI is for copper (0.0005 mg/kg/day).

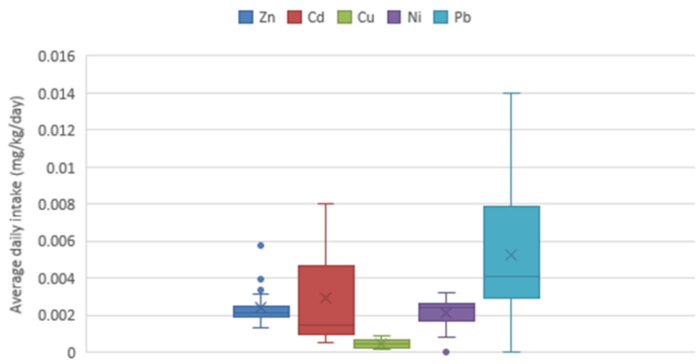

Figure 1. Average daily intake of heavy metals from influent for adults ($CDI_{ingestion}$, mg/kg/day).

Regarding the effluent (Fig. 2), the ingested daily dose, CDI_{Pb} for Pb, is the highest (0.0025 mg/kg/day), being very close to CDI_{Zn} (0.0018 mg/kg/day). The lowest CDI value for the effluent is also characteristic for copper (0.0003 mg/kg/day).

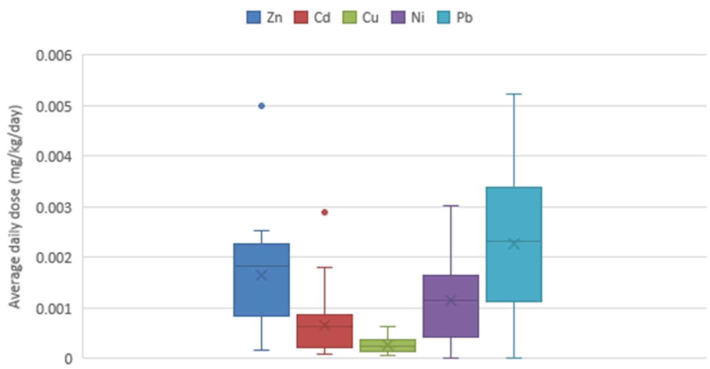

Figure 2. Average daily dose of heavy metals ingested from effluent for adults ($CDI_{ingestion}$, mg/kg/day).

Regarding the risks to children, it can be concluded that the health impact of influent is higher (Fig. 3). CDI_{Pb} reaches 0.02 mg/kg/day, followed by CDI_{Cd} with 0.01 mg/kg/day. The minimum is characteristic of copper with CDI_{Cu} = 0.002 mg/kg/day.

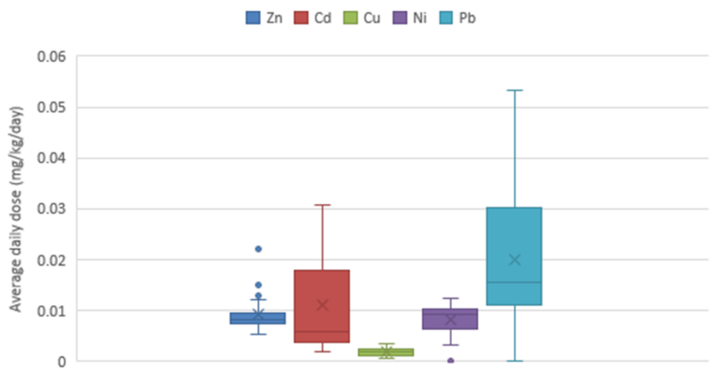

Figure 3. Average daily dose of heavy metals ingested from influent for children ($CDI_{ingestion}$, mg/kg/day).

In this case, the effluent (Fig. 4) has a lower impact on children's health compared to the influent. CDI_{Pb} with 0.009 mg/kg/day being the highest daily dose ingested. Zinc has CDI_{Zn} = 0.006 mg/kg/day. CDI_{Cu} has the lowest value (CDI_{Cu} = 0.0025 mg/kg/day).

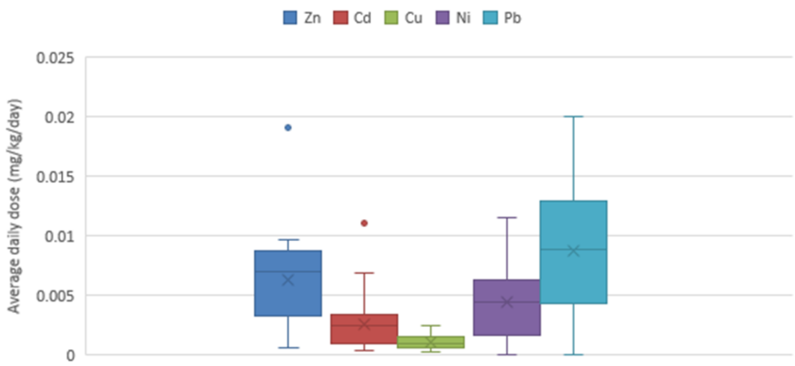

Figure 4. Average daily dose of heavy metals ingested from effluent for children ($CDI_{ingestion}$, mg/kg/day).

As can be seen from Fig. 5, the highest contribution to the ingestion hazard quotient for influent (in the case of adults) is given by cadmium and lead; HQ_{Cd} can exceed 15, and HQ_{Pb} exceed 5. The other investigated chemical elements (Cu, Zn and Ni) have a small contribution to the total HI; when HQ < 1, the health effects from these chemical elements is negligible. 1 < HQ < 10 characterizes a water that can produce possible health effects. HQ > 10 with high probability is defined as a chronic risk [27].

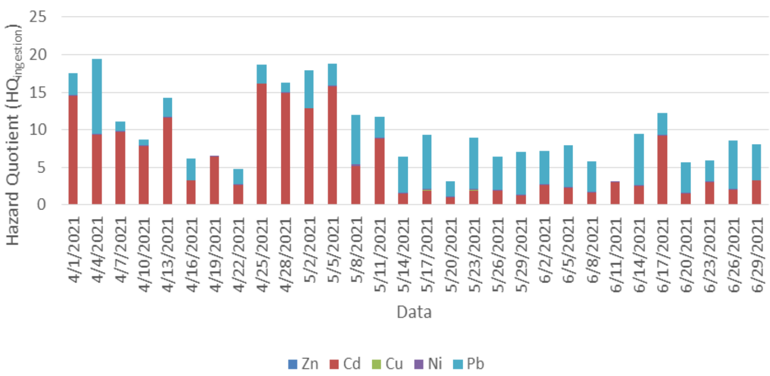

Figure 5. The hazard quotient (total and for each analyzed heavy metal) associated with heavy metals in the influent at ingestion for adults throughout the 91 days of investigations.

On the other hand, the hazard index, HI, for the influent (in the case of adults) on many days exceeds the value of 10, and this clearly demonstrates that the ingestion of influent water is defined as a chronic risk (Fig. 6).

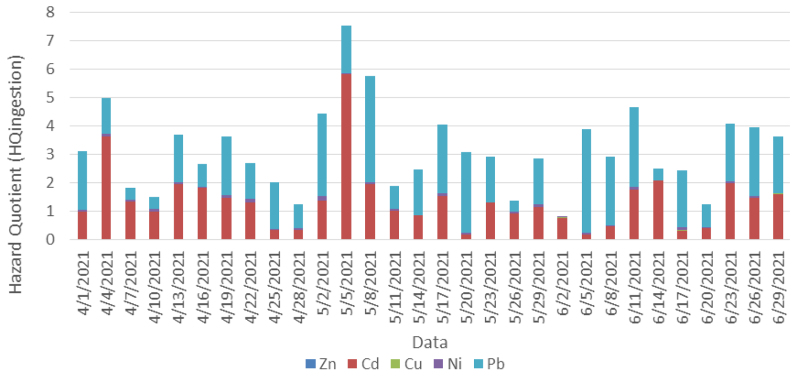

Figure 6. The hazard quotient (total and for each investigated chemical element) associated with heavy metals in the effluent upon ingestion for adults throughout the 91 days of investigations

After the treatment process, all the collected samples registered an HI < 10. In other words, they may present a probable risk to adults if ingested. There are a small number of samples with HI < 1, which theoretically has no adverse health effects related to the target chemicals. Cadmium and lead have the largest contribution to the total hazard quotient. The HQ for children on ingestion is significantly higher compared to adults.

HQ_{Cd} for influent also reaches values of 60, and HQ_{Pb} in some cases exceeds 20. Samples can have HI over 70 and only in a few cases values close to 10. Thus, the impact of influent on children's health (ingestion) is very high (Fig. 7).

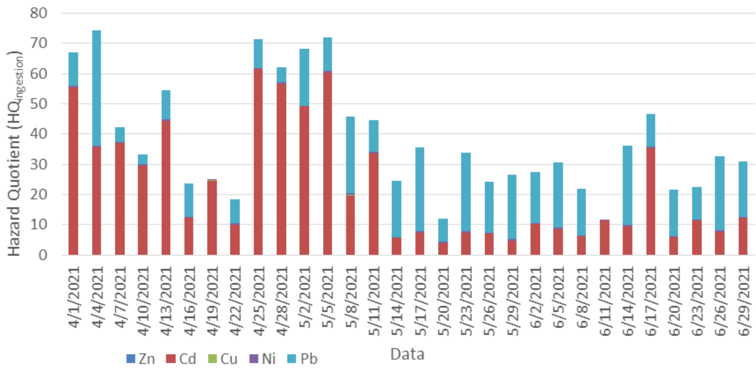

Figure 7. The hazard quotient (total and for each analyzed heavy metal) associated with heavy metals in the influent when ingested by children throughout the 91 days of investigations.

Although the HQ values of the chemical elements, as well as the HI on ingestion are lower for the effluent compared to the influent, in some cases the HI reaches values of 25. In some cases, the HQ_{Cd} exceeds 20 and the HQ_{Pb} exceeds 15 (Fig. 8).

The health impact of cadmium decreases significantly for children on ingestion, although in many cases even the influent has high HI values. Almost half of the samples recorded an HI < 10 regarding the health hazard to children.

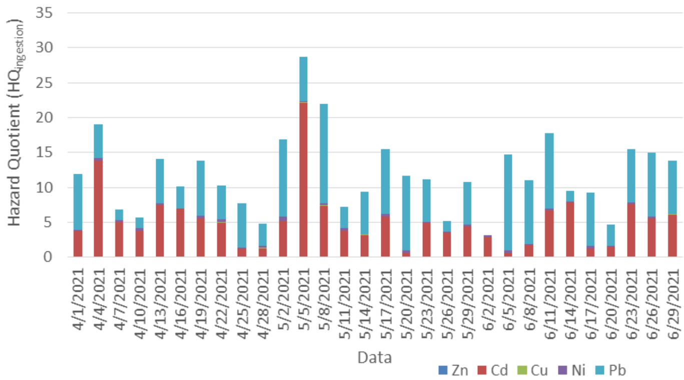

Figure 8. The hazard quotient (total and for each heavy metal analysed) associated with heavy metals in the effluent at ingestion for children.

In addition, these investigations are expanded to absorption of metals at skin level. The chronic daily intake index regarding dermal absorption, CDI_{derm}, was determined for each analysed metals according to equation (1.2) proposed by Custodio et al. (2020) [27] with the input parameters presented in Table 3.

Table 3. Parameters and input assumptions for exposure assessment of metals through dermal pathway.

Parameter	Unit	Values	
		Adult	Children
Skin surface	cm^2	18000	6600
Time of exposure	hours/day	0.58	1.0
Exposure frequency	days/year	365	365
Average human lifetime exposure time	days	25550	2190
Average body weight	kg	70	15
Metal skin permeability coefficient	KP_{Zn} = 0.006; KP_{Cd} = 0.001; KP_{Cu} = 0.001; KP_{Ni} = 0.0002; KP_{Pb} = 0.004		

As can be seen from Fig. 9 the chronic daily dose absorbed through the skin for adults has the highest values for lead ($CDI_{derm-Pb}$ = 0.00015 mg/kg/day) and cadmium ($CDI_{derm-Cd}$ = 0.00009 mg/kg/day). The lowest dermal absorption values are characteristic of copper (CDI_{Cu} = 0.00001 mg/kg/day).

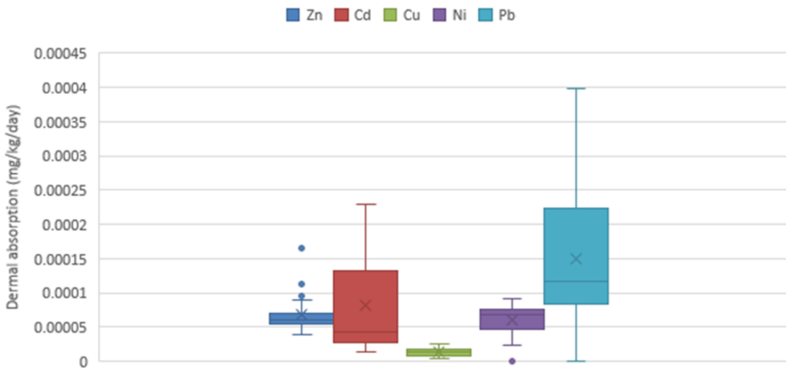

Figure 9. Mean chronic daily dose of heavy metals absorbed through the skin from influent for adults (CDI_{dermal}, mg/kg/day)

Regarding the effluent, the highest values for CDI_{derm} in the case of adults have Pb ($CDI_{derm-Pb}$ = 0.00006 mg/kg/day) and Zn ($CDI_{derm-Zn}$ = 0.00005 mg/kg/day). The lowest values of CDI_{derm} were found for Cu ($CDI_{derm-Cu}$ = 0.00001 mg/kg/day).

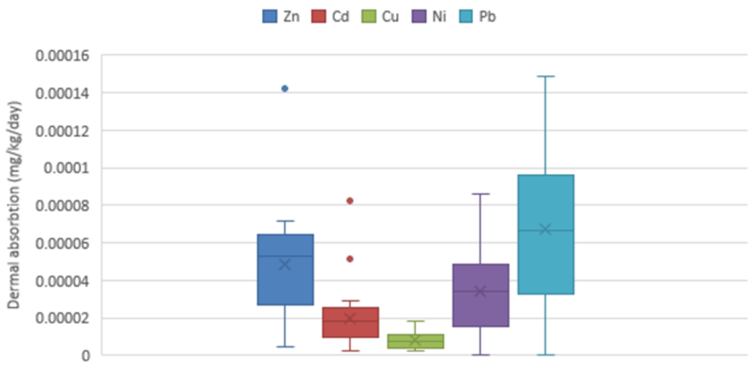

Figure 10. Average chronic daily dose of heavy metals absorbed (CDI_{dermal}) from effluent for adults.

For children, CDI_{derm} for influent has higher values than in adults: $CDI_{derm-Pb}$ = 0.0004 mg/kg/day, $CDI_{derm-Cd}$ = 0.0002 mg/kg/day. For copper, the CDI_{derm} value is 0.0001 mg/kg/day (Fig. 11).

In the case of the effluent, the CDI_{derm} values are lower: $CDI_{derm-Pb}$ = 0.0002 mg/kg/day and $CDI_{derm-Cd}$ = 0.00015 mg/kg/day (Fig. 12).

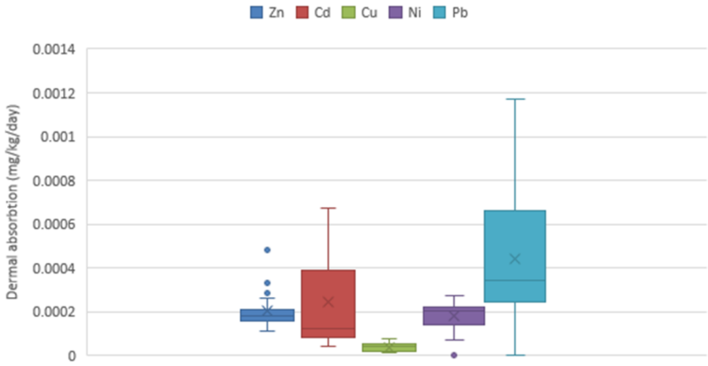

Figure 11. Mean chronic daily dose of heavy metals absorbed (CDI_{dermal}) from influent for children.

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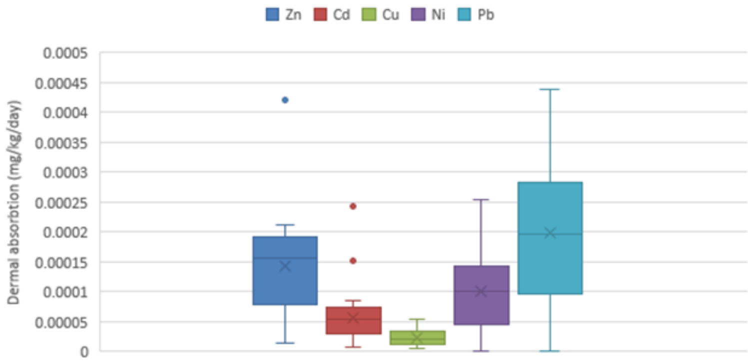

Figure 12. Mean chronic daily dose of heavy metals absorbed (CDI_{dermal}) from effluent for children.

The total hazard quotient for dermal absorption of heavy metals (HI_{derm}) in influent for adults is less than 10 (Fig. 13). At the same time, few samples have $HI_{derm} < 1$, which has low impact related to dermal absorption. The highest contribution to HI_{derm} is given by the cadmium.

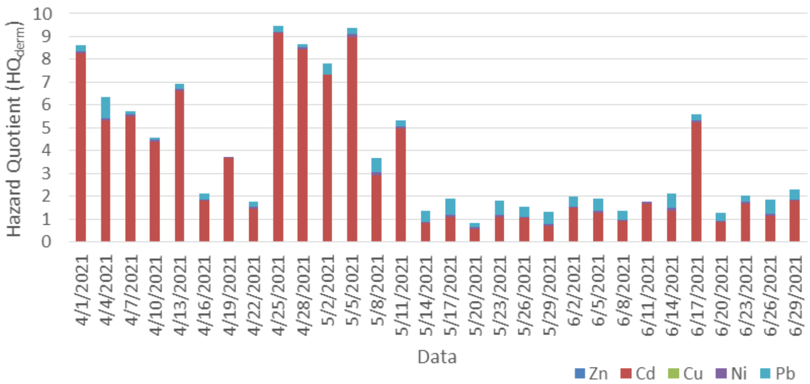

Figure 13. The hazard quotient (total and for each analyzed heavy metal) associated with influent heavy metals for dermal absorption for adults.

Figure 14. **The hazard quotient (total and for each heavy metal analysed) associated with heavy metals in the effluent for dermal absorption for adults**

The total hazard quotient of dermal absorption of heavy metals from the effluent for adults has values < 10, and in most cases, it has values close to 1 (Fig. 14). Thus, for adults, from the point of view of dermal absorption, the effluent has a low or medium impact on health. For children HI_{derm} is quite high and half of the values are higher than 10 (Fig. 15). Thus, the negative effect on health through dermal absorption is quite high.

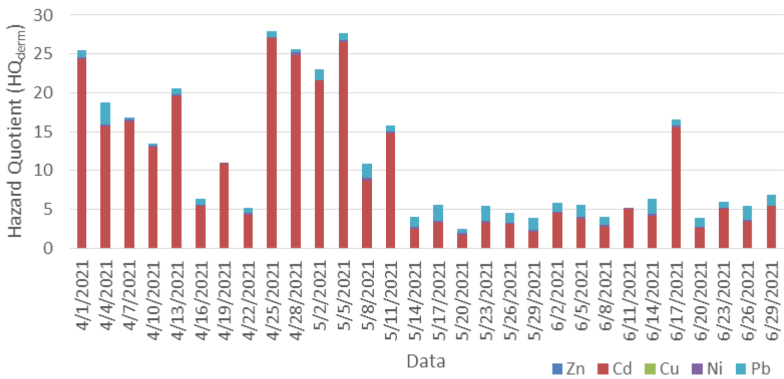

Figure 15. **The hazard quotient (total and for each analyzed heavy metal) associated with influent heavy metals for dermal absorption for children**

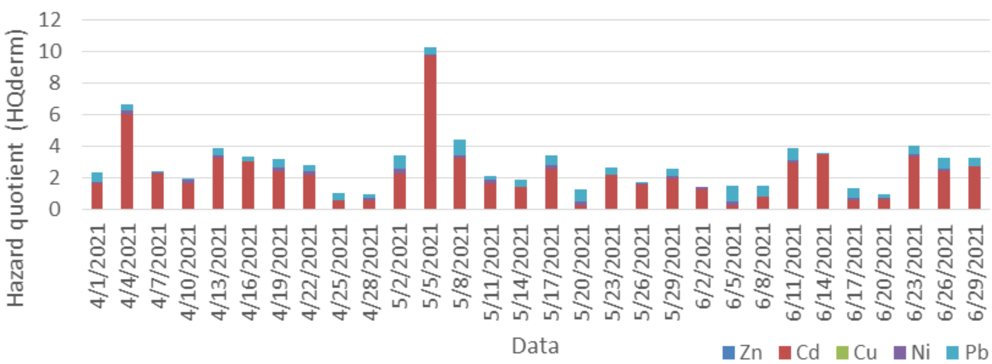

Figure 16. **The hazard quotient (total and for each analyzed heavy metal) associated with heavy metals in the effluent for dermal absorption for children**

Regarding HI_{derm} for effluent (Fig. 16) most samples have this index < 10, the health impact through dermal absorption being low to medium.

Fig. 17 showed the hazard quotients (HQs) according to equation (1.5). For influent it can be seen (Fig. 17) that overall HI_{Pb} is on average 5; HI_{Zn}, HI_{Ni} and HI_{Cu} are quite insignificant. HI_{Cd} has the highest intake, in some cases exceeding 20.

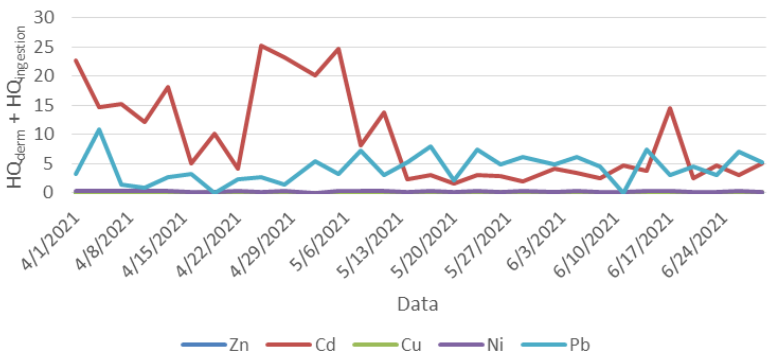

Figure 17. Hazard quotient for each metal (HQ_{derm} + $HQ_{ingestion}$) related to influent/adults.

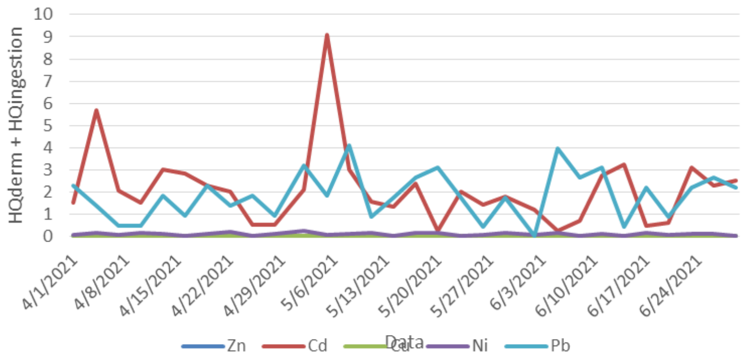

Figure 18. Hazard quotient for each metal (HQ_{derm} + $HQ_{ingestion}$) related to effluent/adults.

For effluent in the case of adults HI_{Me} has close values for Cd and Pb (Fig. 18). No chemical element exceeds 10.

In the case of children, HI_{Me} has rather higher values for influent (Fig. 19). Cadmium has the highest values, reaching values of HI_{Cd} > 70. It can be noticed high values (over 10) for HI_{Cd} and HI_{Pb} during investigation period.

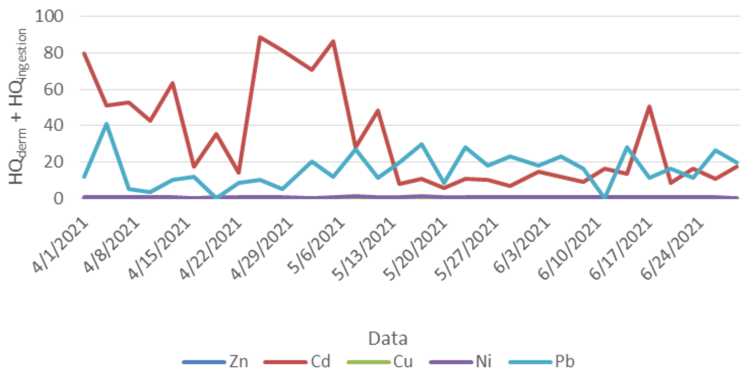

Figure 19. Hazard quotient for each metal (HQ_{derm} + $HQ_{ingestion}$) related to influent/children.

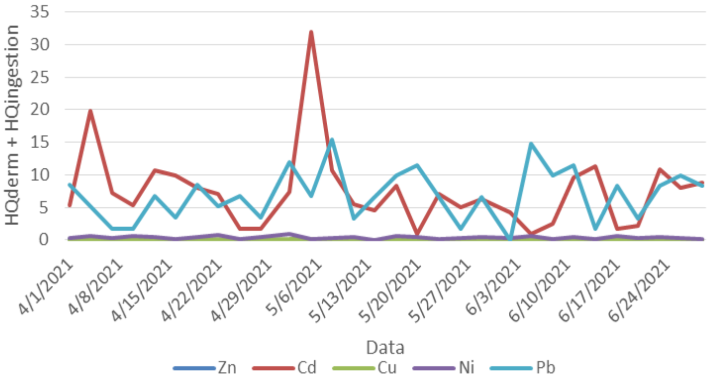

Figure 20. Hazard quotient for each metal (HQ_{derm} + $HQ_{ingestion}$) related to effluent/ children.

From Fig. 20 it can observed that Cd and Pb have quite a high impact on children.

In order to investigate the carcinogenic risk induced by metals included in the category of hazardous element (Cd, Pb and Ni), CR_{ing} was calculated, according to equation (1.7) with the input parameters presented in Table 4.

Table 4. Parameters and input assumptions for exposure assessment of hazardous metals through ingestion pathway.

Parameter	Unit	Values	
		Adult	Children
Daily volume of water ingested	L/day	2.2	1.8
Average body weight	kg	70	15

It is considered that $CR_{ing} < 10^{-6}$ is not characterized by negative health effects. The range $10^{-6} < CR_{ing} < 10^{-4}$ can be considered acceptable under certain conditions, and $CR_{ing} > 10^{-4}$ have major negative health effects [5, 13, 40-43].

From Figs. 21-26, it can be seen that for the three carcinogenic elements, the CR_{ing} values for the influent are, generally higher than the maximum recommended limit to avoid the initiation of cancer (Table 1) for both adults and children. However, the risk of cancer at adults due to cadmium is within the limits in half of the influent samples and within the limits in most of the effluent samples.

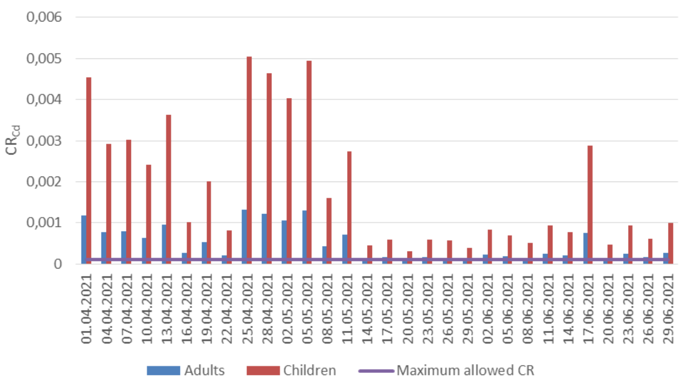

Figure 21. Carcinogenic risk (CR_{Cd}) related to influent cadmium exposure.

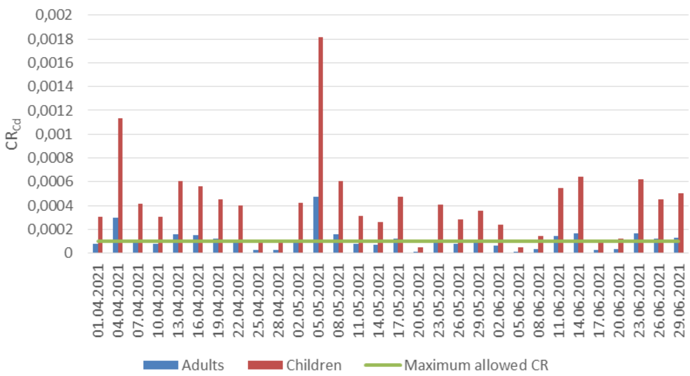

Figure 22. **Carcinogenic risk (CR_{Cd}) related to effluent cadmium exposure.**

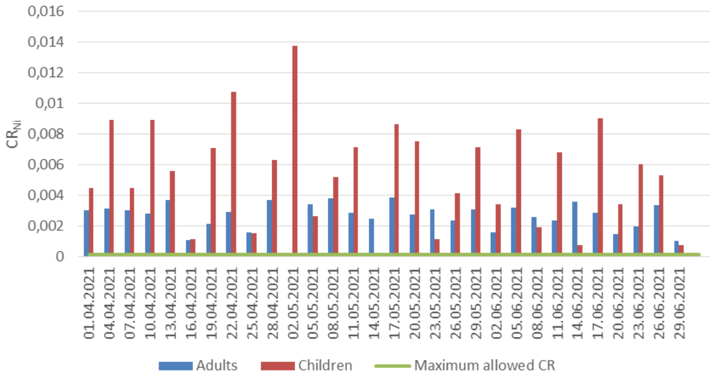

Figure 23. Carcinogenic risk (CR_{Ni}) related to influent nickel exposure.

The risk of causing cancer in both adults and children is higher for nickel than for cadmium.

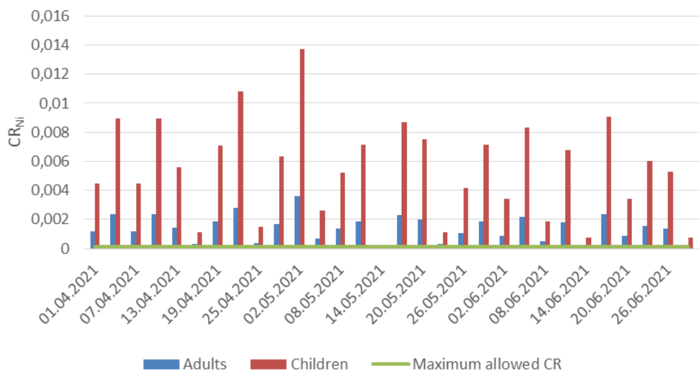

Figure 24. Carcinogenic risk (CR_{Ni}) related to effluent nickel exposure.

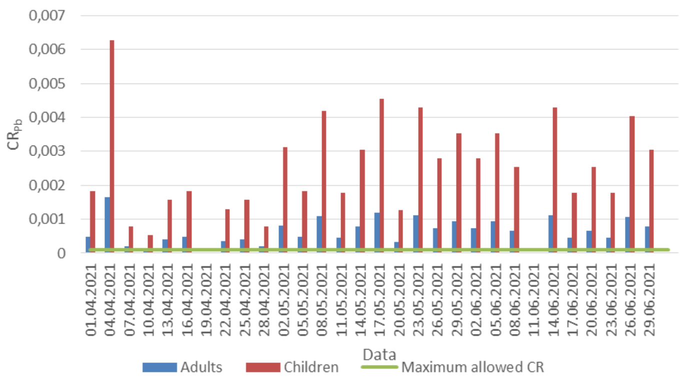

Figure 25. Carcinogenic risk (CR_{Pb}) related to influent lead exposure.

Lead has high CR values compared to the maximum recommended limit for cancer risk.

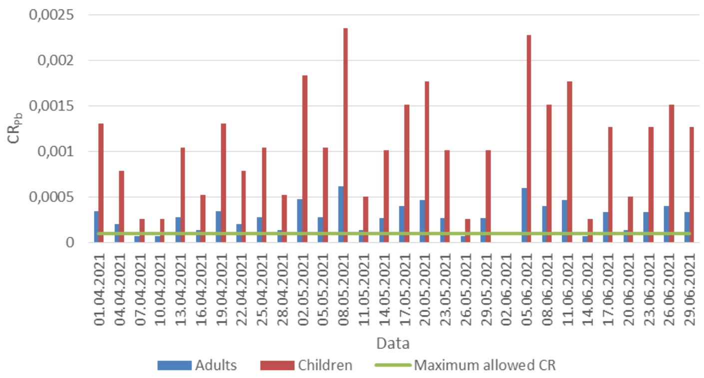

Figure 26. Carcinogenic risk (CR_{Pb}) related to effluent lead exposure.

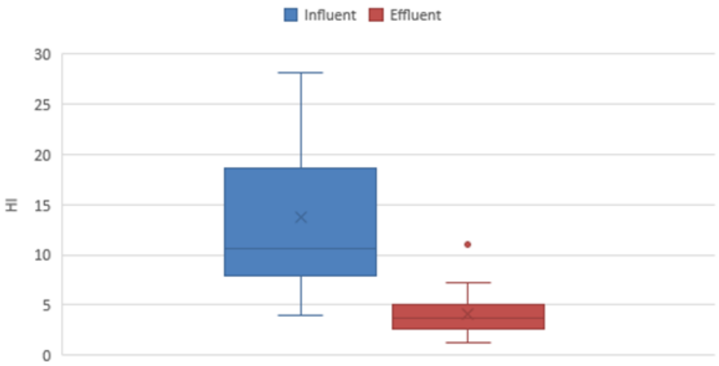

Figure 27. Overall health impact on adults (total hazard index, HI) by both ingestion and dermal absorption.

By comparing the average HI for influent and effluent (Fig. 27), it can be seen that this index decreases by almost 3 times (10 units). In the case of children (Fig. 28), the mean HI decreases in the effluent by almost 30 units. This proves that the purification process has a high impact on decreasing the total toxicity related to heavy metals.

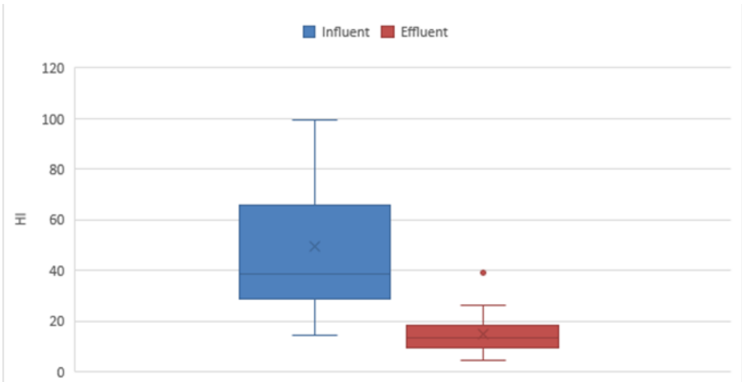

Figure 28. Overall health impact on children (total hazard index, HI) by both ingestion and dermal absorption.

A comparison of the non-carcinogenic risk and carcinogenic risk for adults and children indicated that children were more sensitive and vulnerable than adults when were exposed to the same metals in the influent/effluent.

4. CONCLUSIONS

It should be borne in mind that this study is a probabilistic research based on mathematical formulas and does not involve clinical studies, and the impact on health may be greater or less, depending on other direct or indirect factors.

Regarding dermal absorption, this can only be possible if subjects (adults and children) use the wastewater (influent/effluent) for individual purposes (bathing, swimming, fishing, etc.). If this were theoretically possible, the risks related to the respective water matrices are much higher because in this study only 5 heavy metals (found in the international legislation in the categories of substances with carcinogenic risk) were determined in the waste water, and this it may also contain other substances with different degrees of toxicity. At the same time, for the effluent, the health risk assessment gradient decreases from the wastewater discharge point and is directly dependent on the flow of the natural receptor. In general, the treatment plants have the outlet of the treated waste water into the natural receiver at the exit of the river from the perimeter of the town.

As abovementioned, the results indicate that the wastewater treated in the WWTP, called effluent, cannot be used as drinking water or water intended for domestic consumption. On the other hand, the effluent discharged into a running water, through the lens of the process of dilution and self-purification of the surface water, does not cause harm, if the purpose is recreational, the absorption of carcinogenic metals at the level of a person's dermis is quite small. Cd, Pb and Ni were classified as carcinogenic metals in terms of carcinogenic risk. The values of CR for adults and children exceeded the limit value of 1×10^{-5}, which implied that adults and children had a carcinogenic risk, and this risk was higher for children than for adults. The results of CR for Cd, Pb and Ni implied that Cd was the main pollutant with carcinogenic risk. Moreover, the results indicated that ingestion can be the main pathway.

Even if the effluent falls within the legal limits provided by Romanian legislation, it cannot be classified either as drinking water or as water for bodily use. Surface water treatment legislation at the national and international levels has very well-developed rules regarding the capture of water intended for drinking water, taking care to take it at a great distance from the last point of discharge of wastewater into a river.

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