COMPREHENSIVE HEALTH RISK ASSESSMENT OF DRINKING WATER PRODUCED BY DESALINATION PLANT "CASPIY"[1]

U. Kenessaryiev, A. Dosmukhametov, M. Amrin, A. Yerzhanova, A. Baimukhamedov

Kazakh National Medical University named after S.D. Asfendiyarov
Almaty, Kazakhstan

Abstract. The article uses a case study of drinking water produced by desalination plants "Caspiy" to review the results of predictive comprehensive assessment of drinking water in terms of chemical safety on the basis of non-threshold public health risk assessment. Hazard assessment of source water (Caspian Sea) revealed 11 out of 19 priority pollutants that the water was tested for. The analysis did not reveal any carcinogenic substances. Total risk of reflex and olfactory responses and non-carcinogenic health effects in consumption of drinking water supplied through the distribution network did not exceed the permissible level for individual substances and the compound action. Additional water quality control measures were not required.
Keywords: Kazakhstan; drinking water; non-threshold non-carcinogenic risk.

Introduction. Providing sustainable access to safe drinking water to people living in areas affected by arid and man-made sea pollution is a pressing challenge, and the Republic of Kazakhstan is not an exception. One of the solutions here is conditioning of the mineralized Caspian Sea water.

For example, the city of Aktau has operating desalination units (MAEK-Kazatomprom, LLP); additionally, Caspiy reverse osmosis desalination plant was built and put into operation in 2005. With growing water consumption, such facilities are an economically viable option for the region serving the needs of consumers by providing high quality water.

Meanwhile, ensuring a safe drinking water supply in the Caspian Sea region might be very challenging due to industrial water pollution. Technogenious pollution has a long-term effect on the Caspian Sea and results from the three major sources: toxic river discharges, marine transportation (mainly crude oil and oil products), as well as, crude oil extraction in the sea and the coastal areas. These factors challenge the use of this water body as a source of water supply for the population living in the coastal areas of the Caspian Sea Region in the Republic of Kazakhstan.

The necessity and practicality of using mineralized contaminated sea water as the source of public water supply make it essential to use highly effective sea water purification methods. The choice of water purification methods and their revision must be determined by the minimum health effects associated with consumption of the drinking water of the desired quality.

Therefore, the purpose of this publication is assessment of health risks associated with consumption of treated drinking water (specifically the purification process that takes place at Caspiy facilities).

Research methods and materials. Assessment of public health effects associated with drinking water was conducted following the Guidelines 2.1.10.1920–04 [6].

[1] *Translated by Ksenya Zemnlyanova*

The arrangement of non-carcinogenic chemicals is based on total weights (TW) with consideration of reference doses (RfD) or reference concentrations (RfC). (The Guidelines 2.1.10.1920–04). Thus non-carcinogenic hazard risk index (HRI) was calculated as follows (1):

$$HRI = E*TW*P/10000, \quad (1)$$

Where: HRI – non-carcinogenic hazard risk index;

TW – total weight of the health effect;

P* – size of the population group;

E** – relative exposure level (calculated as average daily intake).

Since the population group under exposure is assessed as population at large (Aktau), P/ 10 000 is not accounted for in HRI and HRIc calculations.

Similarly, comprehensive toxicity assessment of chemical compounds in drinking water was conducted following the guidelines in MR 2.1.4.0032–11 [7].

All the calculations are based on predicted risk assessment associated with the planned launch of Caspiy. The risk assessment was conducted according to the reference doses of the tested chemicals (12 compounds) and maximum permissible concentration MPC (7 compounds).

The assessment was conducted for peroral exposure with the use of the following standard values recommended by the WHO [6]: water consumption – 2 l/day, exposure frequency – 36 days; exposure length – 30 years; body mass – 70 kg; identification period, number of days – 30 years, 365 days each. Maximum daily exposure is agreed to be 24 hours.

Reflex and olfactory responses risk assessment was conducted only for significant indicators of organoleptic water properties, with the risk value equated to zero at low indicator values (Prob) (chlorine residual and fixed, chlorides). The assessment of the total risk was conducted by selecting the maximum value in the group of all values characteristic of each of the chemicals [5].

Results and discussion. Review of the project documentation shows that the water treatment process (the Caspian Sea) is based on water filtration with coagulation and flocculation, reverse osmosis desalination and pH adjustment of the fresh water. This treatment process is a purification solution for source water that contains chemical contaminants and oil products. Caspiy uses selective membranes with high oil filtration levels; filtration efficiency equals 99.5% even for high (approx. 3.0 mg/l) source levels.

Nineteen chemical compounds were registered in the source water and pre-arranged at the hazard identification state of which 11 were categorized as priority compounds including common sea water compounds: chlorides, sulfates and organic compounds registered by such water quality indicator as ‘dry residue’. The analysis showed that the identified compounds entering a human body with drinking water in amounts exceeding the reference values could induce dysfunction of the critical organs/systems: nervous system, blood circulatory system, gastrointestinal system, kidney, tooth and bone tissues, and reproductive system.

Carcinogenic compounds were not revealed in the source water. The following average daily intakes were calculated at the exposure assessment stage for peroral exposure to the identified compounds through drinking water consumption (Table 1).

Table 1

Estimated average daily intake (I) of compounds contained in water at the post-conditioning stage, mg/(kg-day)

№	Indicator	Chemical concentration, mg/l	RfD, mg/kg-day	I (average daily intake), mg/kg-day
1.	Sodium	6,05	34,3	0.166
2.	Calcium	30	41,4	0,822
3.	Magnesium	0.67	11	0.018
4.	Sulfates	38,75	-*	1,062
5.	Chlorides	10.07	-*	0.276
6.	fluoride	1,01	0.06	0.028
7.	Bromine	0.14	1	0.004
8.	Boron	0.36	0.2	0.010
9.	Dry residue	133,14	-*	3,648
10.	Hydrocarbonates	44,13	-*	1,209

*Reference doses not determined

The highest average daily intake values were registered for sulfates (1.06), hydrocarbonates (1.209) and dry residue (3.648) which do not have determined reference doses. The average daily intake values for other compounds (except for chlorides) were significantly lower as compared to the reference levels.

Characteristics of the main organoleptic water quality indicators and their compounds were identified at the stage of risk assessment of reflex and olfactory responses (Table 2).

Table 2

Risk assessment of reflex and olfactory responses in drinking water

Analysis parameter	Value	MPC, mg/l	Prob <*>	Risk
Odor at 20 °C	0	2		0
Taste at 20 °C	0	2		0
Colority	0	20	-3,33	0
Cloudiness	0	1,5	-3	0
Hydrogen concentration	7,9	9	-3,1	0.001
Total hardness	3	7	-3,22168	0.0007
Chlorides	41	350	-5,09186	0
Dry residue	228	500	-3,13224	0.001
Free residual chlorine	0.08	0.5	-4,64232	0
Fixed residual chlorine	0.06	1,2	-6,31942	0
Total risk of reflex and olfactory effects				0.001
Permissible level of reflex and olfactory responses				0.1

<*> Here 'Prob' is an intermediate value for transition from the hazardous chemical concentration to health risk

The total organoleptic risk assessment of contaminants in this drinking water equaled 0.001; priority factors included dry residue and hydrogen concentration.

Table 3 provides summary data from the non-carcinogenic risk assessment for the model environment of water treatment at Caspiy desalination plant.

Table 3

Non-threshold non-carcinogenic risk values (Risk) for chemicals in drinking water after desalination plant treatment and before going into the water supply network

Indicator	MPC	Water after conditioning filters		Water flow after radiation chamber	
		Chemical concentration, mg/l	Risk	Chemical concentration, mg/l	Risk
Sulfates	500	69	0.0024	6,05	0.0005
Chlorides	350	41	0.0020	30	0.0037
Fluoride	1,5	0.24	0.0028	0.67	0.0001
Dry residue	1000	228	0.0040	38,75	0.0014
Free residual chlorine	0.5	0.08	0.0028	10.07	0.0005
Fixed residual chlorine	1,2	0.06	0.0009	1,01	0.0117
Permissible risk level of chronic intoxication			≤0.02		≤0.02
Total non-threshold non-carcinogenic risk			0.01476		0.046
Permissible total non-threshold non-carcinogenic risk			≤0.05		≤0.05

According to Table 3, non-threshold non-carcinogenic risks associated with specific chemicals under review do not exceed permissible exposure (0.02). Total non-threshold non-carcinogenic risk assessment values for contaminants in drinking water equal 0.046 which does not exceed the permissible level (0.05).

Overall, non-threshold, non-carcinogenic public health risks associated with the quality of drinking water in the distribution network do not exceed permissible levels both for individual chemicals and for compound action.

As risk description is the final stage of risk assessment and the first stage of risk management, we conducted a comprehensive risk analysis (summation effects) of the drinking water in the distribution network.

Table 4 below shows the results of the comprehensive risk analysis of the drinking water.

Table 4

Integral performance index calculation for drinking water

Type of risk	Integral estimation value	Permissible value	Risk / Permissible value ratio
Reflex and olfactory response risk	0.001	0.1	0.01
Non-carcinogenic risk	0.015	0.05	0.30
Carcinogenic risk	0	0.00001	0.0
Integral index			0.31

of all the tested risk indicators did not exceed the permissible levels and did not require additional Table 4 shows that the ratio of reflex and olfactory response risk and permissible value equals 0.01, and the ratio of combined non-carcinogenic risk and its permissible level

equals 0.3. The integral performance index totals 0.31 which is below the specified level (IPI≤1). Overall, the values measures for water quality management.

At the uncertainty analysis stage, the following factors connected to uncertainties in risk analysis were considered: determination of reference doses, relevance, accuracy of extrapolation, acceptability of the scientific data, registration of all the routes of entry of the tested substances into the body, and specifics of the epidemiological studies. Taking into account the indicated uncertainties at the next water treatment stages will minimize risks, increase objectivity of conclusions and validity of management decisions.

Conclusion. The case study of drinking water produced by Caspiy Desalination Plant, LLP is the first risk assessment of this kind conducted in the Republic of Kazakhstan. Risk assessment studies conducted based on harmonization approach in accordance with the current RF regulatory and procedural guidelines [7, 8] has shown that 11 priority source water compounds (including chlorides, sulfates, dry residue, etc., HRI≥100) can serve as the leading non-carcinogenic risk factors. Carcinogenic substances were not detected in the source water.

Estimated average daily intake values for all the tested compounds in the drinking water after treatment were below the reference dose values indicating no health hazard.

Total assessment risk is acceptable in chronic intoxication by individual substances and compounds (integral performance index for summation effects totaled 0.31 which does not exceed the regulated level (IPI ≤1)). For this reason, recommendations for management decisions are not needed, following the risk assessment guidelines.

Overall, the data indicates that the drinking water treated by reverse osmosis at the Caspiy reverse osmosis desalination plant is not hazardous in its chemical composition to human health.

References

1. Avaliani S.L., Filatov N.N, Aksenova O.I. i dr. Razrabotka i aprobatsiya metodiki otsenki riska zdorov'yu naseleniya ot promyshlennykh predpriyatiy i avtotransporta na territorii YuVAO g. Moskvy [The development and validation of a methodology for assessing human health risks from industrial companies and motor vehicles in the Moscow South-Eastern Administrative Okrug]. *Okruzhayushchaya sreda. Otsenka riska dlya zdorov'ya. Opyt primeneniya metodologii otsenki riska v Moskve*. Moscow: TsGSEN, RMAPO, 1999. pp. 3–45.

2. Avaliani S.L., Aksenova O.I., Ponomareva O.V. Razrabotka i vnedrenie metodologii otsenki riska zdorov'yu naseleniya ot vozdeystviya zagryazneniya atmosfernogo vozdukha i pit'evoy vody na territoriyakh g. Moskvy [The development and implementation of a methodology for assessing human health risks from exposure to ambient air and drinking water pollution in Moscow]. Moscow: Konsul'tatsionnyy tsentr po otsenke riska, TsGSEN v g. Moskve, 2000.

3. Avaliani S.L., Revich B.M. Otsenka riska zagryazneniya okruzhayushchey sredy dlya zdorov'ya naseleniya kak instrument munitsipal'noy ekologicheskoy politiki v Moskovskoy oblasti [Human health risk assessment of environmental pollution on as a tool of municipal environmental policy in the Moscow Region]. Moscow, 2010. 311 p.

4. Onishchenko G.G., Novikov S.M., Rakhmanin Yu.A., Avaliani S.L., Bushtueva K.A. Osnovy otsenki riska dlya zdorov'ya pri vozdeystvii khimicheskikh veshchestv,

zagryaznyayushchikh okruzhayushchuyu sredu [The foundations of human health risk assessment of exposure to environmental pollutants]. Moscow, 2002. 408 p.

5. Shcherban' M.G., Myasoedov V.V., Shevchenko O.O., Savchenko V.M. Metodicheskie aspekty ispol'zovaniya metodologii otsenki riska zdorov'yu naseleniya pri vozdeystvii faktorov okruzhayushchey sredy v Ukraine i Rossii [Methodological aspects of the use of a methodology for health risk assessment of exposure to environmental factors in Ukraine and Russia]. Available at: http://www.nbuv.gov.ua/portal/natural/vkhnu/Med/2010_898/17.pdf.

6. R 2.1.10.1920-04. Rukovodstvo po otsenke riska dlya zdorov'ya naseleniya pri vozdeystvii khimicheskikh veshchestv, zagryaznyayushchikh okruzhayushchuyu sredu [R 2.1.10.1920-04. Guidelines for human health risk assessment of exposure to environmental chemical pollutants]. Utv. Glavnym gosudarstvennym sanitarnym vrachom RF 05.03.2004. Available at: http://www.bestpravo.ru/rossijskoje/lq-zakony/j7b.htm.

7. MR 2.1.4.0032-11. 2.1.4. Pit'evaya voda i vodosnabzhenie naselennykh mest. Integral'naya otsenka pit'evoy vody tsentralizovannykh sistem vodosnabzheniya po pokazatelyam khimicheskoy bezvrednosti. Metodicheskie rekomendatsii [MR 2.1.4.0032-11. 2.1.4. Drinking water and water supply of residential areas. An integral assessment of centralized drinking water supply systems based on chemical safety indicators. Methodical guidelines]. Utv. Glavnym gosudarstvennym sanitarnym vrachom RF 31.07.2011. Available at: http://www.garant.ru/products/ipo/prime/doc/12090808/.

8. Rukovodstvo po kontrolyu kachestva pit'evoy vody: rekomendatsii [Guidelines for drinking water quality monitoring. Recommendations]. Zheneva: World Health Organization, 1986, vol. 1, 2.

9. U.S. Environment Protection Agency. Available at: http://www.epa.gov/html/emci/chemref/60297/60297.

10. Mel'tser A.V., Kiselev A.V., Erastova N.V., Shul'ga A.A. Integral'naya otsenka pit'evoy vody po pokazatelyam khimicheskoy bezvrednosti na osnove metodologii otsenki riska dlya zdorov'ya naseleniya, aprobirovannaya na vodoprovodnykh stantsiyakh GUP «Vodokanal Sankt-Peterburga» [An integral assessment of drinking water according to chemical safety indicators based on the methodology for human health risk assessment, applied at the "Vodokanal of St. Petersburg" water supply stations]. *Materialy 2-y Vserossiyskoy nauchno-prakticheskoy konferentsii s mezhdunarodnym uchastiem «Gigienicheskie i mediko-profilakticheskie tekhnologii upravleniya riskami zdorov'yu naseleniya».* Perm', 2011, pp. 574–158.

About the authors:

Kenesariev Usen Ismagilivich – D. Sc (Med), Head of Department of common hygiene and ecology, leader research fellow of public health risk assessment laboratory in Kazakh national medical university named after S.D. Asfendiyarov of Ministry of Health (94 Tole Bi st, Almaty, Kazakstan, postal code 050012, e-mail: kenesary@inbox.ru,Tel.: 8 (727) 29-26-722).

Dosmuhametov Ashat Tursynhanovich – PhD, docent of Department of common hygiene and ecology, leader research fellow of public health risk assessment laboratory in

Kazakh national medical university named after S.D. Asfendiyarov of Ministry of Health (94 Tole Bi st, Almaty, Kazakstan, postal code 050012, e-mail: zhantore@mail.ru, Tel.: 8 (727) 29-26-722).

Amrin Meyram Kazievich – PhD, docent of Department of common hygiene and ecology, leader research fellow of public health risk assessment laboratory in Kazakh national medical university named after S.D. Asfendiyarov of Ministry of Health (94 Tole Bi st, Almaty, Kazakstan, postal code 050012, e-mail: amrin_m@mail.ru,, Tel.: 8 (727) 29-26-722).

Erzhanova Aya Eralyvna – PhD, head teacher of Department of common hygiene and ecology, leader research fellow of public health risk assessment laboratory in Kazakh national medical university named after S.D. Asfendiyarov of Ministry of Health (94 Tole Bi st, Almaty, Kazakstan, postal code 050012, e-mail: aya.er@mail.ru, Tel.: 8 (727) 29-26-722).

Bajmuhamedov Arman Azamatovich – PhD, research fellow of public health risk assessment laboratory in Kazakh national medical university named after S.D. Asfendiyarov of Ministry of Health (94 Tole Bi st, Almaty, Kazakstan, postal code 050012, e-mail: st.luca@bk.ru,, Tel.: 8 (727) 29-26-722).