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Review

Health Impact of Drying Aral Sea: One Health and Socio-Economical Approach

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Abstract: Once one of the largest saline lakes, the Aral Sea, was recognized as a significant environmental disaster as the water level decreased dramatically. Water level decrease increases water salinity, affecting biodiversity. Exposed lake beds become the source for fine dust picked up by the dust storms and spread across a long distance, affecting people's health in surrounding areas. This review paper attempts to evaluate the potential links between the Aral Sea shrinking and the existing health issues in the case of Kazakhstan. The literature-based research revealed that the population of the Aral Sea basin region has been suffering from exposure to various pollutant residues for a long time. There is an apparent increase in morbidity and mortality rates in the region, especially in people suffering from chronic illness. Furthermore, the catastrophic desiccation of the Aral Sea has led to the sharp deterioration in living conditions and negative trends in the socio-economic situation of the region's population. While the dust storms spread the polluted salts from the exposed bottom across the Aral Sea region, specific contaminants define the relevance and importance of public health problems linked to the basin rather than the Aral Sea drying process. There is, however, no clear evidence that associated dust storms are the only primary source of the deterioration of people's health. Moreover, One Health approach seems to play a crucial role in achieving better outcomes in the health of people and the health of the environment.

Keywords: Aral Sea desiccation; water pollution; One Health approach; socio-economic aspects; Kazakhstan

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1. Introduction

Environmental factors are significant contributors to the health of people [1]. About 23% of global deaths and 22% of global disability-adjusted life years (DALYs) were due to environmental risks in 2012, which could have been prevented [2]. As it is a concern for many countries, the "One Health" approach has been adopted by collaborating and coordinating the joint efforts of responsible authorities [3,4]. The idea represents the concept of "One Health for the entire ecosystem" as interventions and interconnections among living species. Thus, the main goal is to achieve the best health outcomes for people, animals, plants, and the environment through the cooperation of experts in human health (doctors, nurses, public health practitioners, epidemiologists), animal health (veterinarians, paraprofessionals, agricultural workers), environment (ecologists, wildlife experts), and other related areas of expertise.

While Sustainable Development Goal 3 (SDG 3) considers the importance of decreasing the risks for health caused by air and water pollution, SDG 6 ensures the health of water resources and the sustainable and universal access of everyone to safe water and sanitation [5,6]. According to The Global Burden of Diseases, Injuries, and Risk Factors Study [7], water pollution caused 1.8 million deaths in 2015 compared to 0.84 million in 2012. Consequently, effective handling of domestic, industrial, and agricultural pollution emissions provides benefits for the environment and public health [8].

Once one of the largest saline lakes, the Aral Sea, has been recognized as one of the significant environmental disasters as the water level decreased dramatically in recent years [9] and is one of the examples of a clearly unsustainable case [10]. Water withdrawal for irrigation was a primary reason for the desiccation of the lake. The decrease in water level causes an increase in water salinity and consequently affects biodiversity. In many related cases, the shrinking of saline lakes speeds up the anthropogenic impact rather than the long-term effect of climate change [11,12]. The salt crusts, formed on the dry bottom of the former lake, are rich in various minerals like sodium, chloride, magnesium, calcium, sulfates, borate, lithium and potassium [13]. Minerals from Lake Munclin (Sahara desert) and the Dead Sea are used as fertilizer, salt from Lake Minchin, at present called Salar de Uyuni salt pan in Bolivia, is extracted for table salt and lithium and Bristol Lake in California is extracted for industry and food products [14] and salts from the shrunk bottom of Lake Zuni are used for pharmaceutical purposes [15]. Therefore, several economic benefits due to desiccation, such as mineral extraction, might contradict direct economic losses of affected fisheries, collapsed infrastructure, deteriorated ecosystems, and subsequent environmental costs, like in the Aral Sea case [16].

Moreover, after the USSR collapsed, there has been a consistent tendency of the number of citizens who have left the country exceeding the number of entrants in Kazakhstan. A comparison of the Soviet census of 1989 and Kazakhstan in 1999 shows a decrease in the republic's population for 10 years 1 million 511 thousand people [17], and mainly from the Aral Sea region—a decrease of the population to 18.3% [18]. However, exposed lake beds affect public health [19] as they become the source of fine dust, which is picked up by the dust storms and spread across long distances. It is assumed that people who live nearby drying lakes face several health disorders [20]. Considering the possible health effects, the Republic of Kazakhstan is tackling environmental degradation around the Aral Sea in the Kyzylorda region and related social and public health issues [21]. Several state-run and regional programs aimed at improving the quality of life of people have been launched to assess the problems of the Aral Sea regions using a One health and system approach and provide comprehensive solutions to improve the situation [22,23].

Consequently, this paper considers the case study of Kazakhstan and investigates the linkages between the Aral Sea shrinking and the existing health issues and social-economic processes in the Aral Sea region. Numerous studies regarding the health of the population living in the Aral Sea region have been conducted in the past, making it an ideal case study for health condition analysis. The literature search process included four main parts: firstly, the reports and articles published in the peer-reviewed journals were found. Secondly, the available materials in Russian language, published in local journals and related sources, were investigated. Thirdly, the reports of medical screenings and medical studies, performed by local medical organizations were studied. The main limitation of those sources is that the local researchers mainly did not aim to investigate the direct links between health issues and environmental degradation but focused only on the population's health conditions. Fourthly, the official statistics from the region, and additionally several random interviews were conducted with the locals to consolidate populations' socio-economic development.

The instance of Aral perfectly fits and establishes conditions for adopting the One Health approach which may arise from a systemic view ranging across scales from molecules to the ecological and socio-cultural context, as well as from the comparison with different disease endemicities and health systems structures. Therefore, in this article, the authors reviewed each factor separately and tried to show their interdependence which is the primary tool of the One Health approach and allows for interdisciplinary research of Aral Sea case.

2. Study Area

2.1. Description of the Study Area

Once the fourth largest lake in the world [24], the Aral Sea has two main tributaries: the Amu- Darya river from the North and Syr -Darya river from the South-East, as shown in Figure 1.

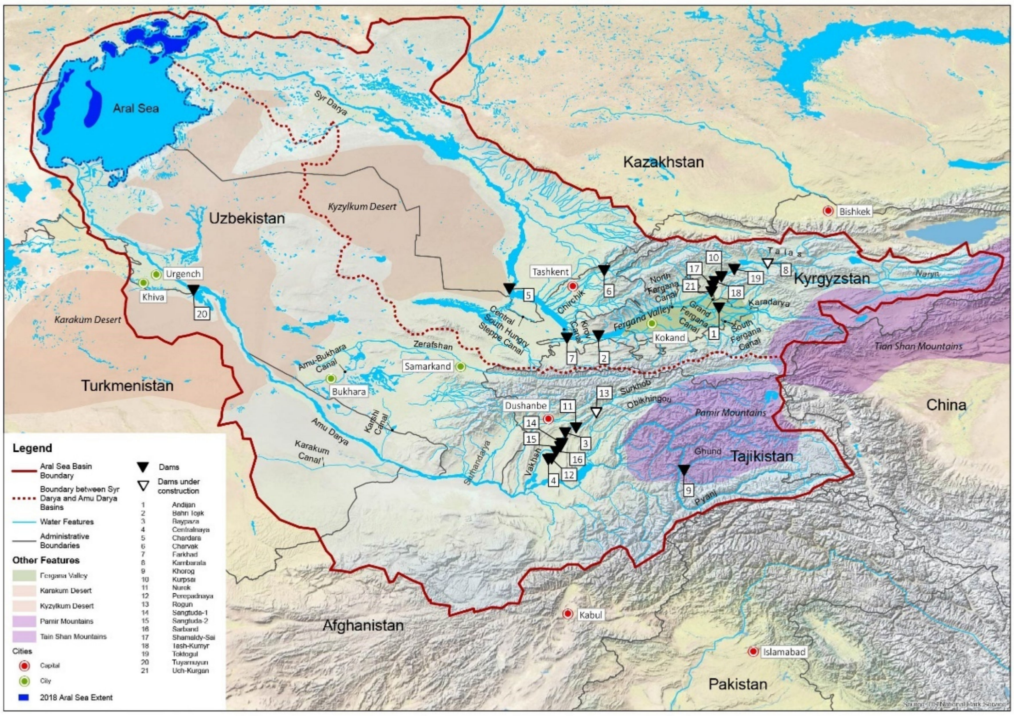

Figure 1. Aral Sea Basin [24]. Reproduced with permission from Hamid Mehmood, Aral Sea Basin book; published by Routledge, 2020.

In 1960, the total area of the Aral Sea was 68,478 km^2 with a water capacity of 1093 km^3 and a water level 53.4 m above mean sea level. After that, the water level started to decrease extremally (Figure 2). During 1960–1986, the water level decreased from 53.4 m to 41.02 m due to the decline of water inflow [25]. The Soviet Union tried to save the Sea and built a Kokaral dike in 1986. Thereon, this construction split the Aral Sea into the North Aral Sea (NAS) and South Aral Sea (SAS) [26]. Currently, the hydrological boundaries of NAS belong to Kazakhstan with a water volume of 80 km^3, an average depth of 13.3 m and a maximum depth of 29 m. SAS, belonging to Uzbekistan, had a territory of 60,000 km^2 and a water volume of 984 km^3. The Amu- Darya tributary fed SAS. As a subject for water management conflict between several countries in Central Asia, the water inflow diminished, and the SAS was further split into East and West Aral Sea. However, the East Aral Sea was shallow with a max depth of 28 m and an average depth of 14.7 m and the West Aral Sea was deeper with a max depth of 69 m and an average depth of 22.2 m [27]. Water level changes are represented in Figure 2.

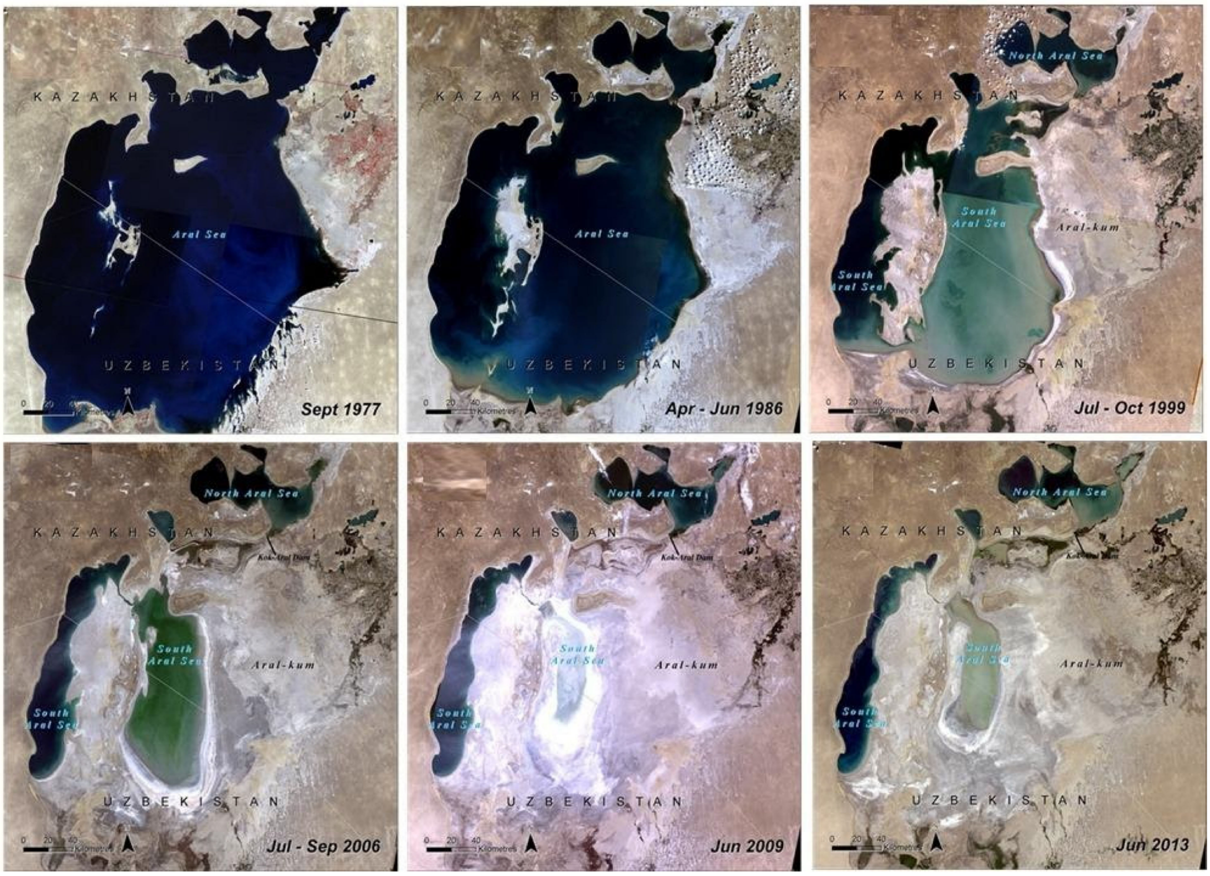

Figure 2. Landsat satellite imagery mosaics showing visible changes of the Aral Sea.Source: USGS/NASA; visualisation by UNEP/GRID-Sioux Falls.

The population in Central Asia rose from 10.5 million to 24.7 million during 1897–1959 [28]. This increase in population demanded more agricultural products for sustenance. There was an increase in cotton irrigation during the 1980s, which attracted people to migrate to the Aral Sea basin (ASB) from other parts of the Soviet Union [29]. The increase in water withdrawal from the Amu- Darya and the Syr- Darya for industrial, agricultural [30] and domestic use, limited water flow into the Aral Sea. This led to the shrinking of the Aral Sea [31,32]. Moreover, the return flow was contaminated with industrial and agricultural wastewater.

2.2. Description of the Area Based on the Environmental Impact (Based on the Law)

The law in Kazakhstan "On the social protection of citizens affected by the environmental disaster in the Aral Sea region" [23] divided the study area into three zones by administrative division: catastrophe, crisis, and pre-Crisis. The criteria for determining the boundaries were (1) for the catastrophe zone: steady growth of mortality rate, forced migration for environmental reasons, enormously exceeded concentrations of the pollutants in the environment, destruction of ecosystems, and their loss of the ability to self-recovery, catastrophic shallowing of the water bodies; (2) for the crisis zone: steady growth in the specific morbidity of the population, significantly exceeding the standards of maximum permissible discharge of the pollutants in the environment, a reduction in the species composition and a decrease in the biological productivity of ecosystems by 75 percent, desiccation of water bodies; and (3) for the pre-crisis zone: a steady increase in the ecology-linked diseases, stable exceeding of the concentrations of the pollutants in the environment, reduction in the species composition and a decrease in the biological productivity of ecosystems by 50 percent, desiccation of water bodies. Authors recognized that the scientists have mainly studied the following localities: in the catastrophe zone—Aralsk, Kazalinsk, Shalkar, which is within 0–250 km; in the crisis zone—Karmakshy, Zhalagash, which is within 250–370 km; and in the pre-crisis zone—Arys, Irgiz, and Ulytau, which is 370–810 km from the Aral Sea. The study named "Integrated approaches in managing the health of the Area population" was carried out by the ministry of health and social development of Kazakhstan to investigate people's health in all the zones mentioned above and compare it to a control zone. These zones were compared to a control region (Zhanaarka), which was beyond 811 km from the Aral Sea (Figure 3).

Figure 3. The study area of the Aral region in Kazakhstan, Kyzylorda region.

3. Exposure of Risks

3.1. Exposure to Chemical Pollutants

Since the 1960s, during the Soviet Union period, pesticide chemicals like dichlorodiphenyldichloroethylene (DDE), butiphos, propanide, hexachlorocyclohexane (HCH), and dichlorodiphenyltrichloroethane (DDT) were used in vast quantities in the Aral drainage basin region even though these have been banned in the rest of the world [28]. Wastewater contaminated with toxic chemicals from 146 collector-drainage systems was discharged to the Syr- Darya River. More than 70% of them are outside the Kyzylorda region in Kazakhstan [33]. Along with pesticides that are dangerous to the health of the region's inhabitants, there was excessive contamination of the Syr- Darya River with heavy metals and persistent organic compounds (POC) that include polychlorinated biphenyl, polychlorinated dibenzodioxins, and polychlorinated dibenzofurans. They were used as coolants and lubricants in both industrial and mining activities. The primary source of discharge was from the activity of refineries such as Ispat-Karmen, Balkhashmys, Akchatau, Zhezkazgantsvetmet, Shalkiya and Shymkent, which points to the high activity of both mineral and metallurgical industries in the area.

Furthermore, studies on body burdening pollutants have shown traces of hexachlorobenzene (HCB), hexachlorocyclohexane (HCH), dichlorodiphenyldichloroethylene (DDE), and dichlorodiphenyltrichloroethane (DDT) chemicals in the blood plasma of pregnant women [34]. Polychlorinated biphenyl (PCB) and persistent organic compound (POC) also have been found in breast milk [35]. The blood lipid among children in the study region contained DDT and HCH, typical organochlorine compounds' representatives [36]. The organochlorine compounds are carcinogenic and cause neurological damage and chronic health issues [37]. Apart from this, metals like nickel, copper, cobalt, zinc, arsenic, and selenium are also found in the human body [34]. The mining industry is one of the contributors to pollution in the region [38]. Samples of butter, cottonseed oil and cooking oil were collected to test whether the contaminated water affects the food chain of people around the Aral basin. They found 2,3,7,8-tetrachlorodibenz-para-dioxin (TCDD) in the cottonseed and HCH in butter, sheep meat, eggs, carrots, and onions affected by these toxic chemicals [39,40].

3.2. Salinity Implications on the Health

Salts play a significant role in the body and function as an electrolyte, which helps the nervous system to work correctly [41]. The kidney helps in regulating electrolyte concentration in the body [42]. However, an increase in salt concentration may disrupt standard biological mechanisms and lead to several diseases [43]. Since the salt level has been very high in the basin, people who utilize the water have suffered from diseases like hypertension, hypercalciuria, cardiovascular diseases, high blood pressure, kidney stone, and bone metabolism [44].

The desiccation of the Aral Sea led to salinization of the soil within the irrigated areas of the basin and a higher level of salinity of the groundwater, coupled with the salinization of belonged rivers and channels [45–47]. Due to increasing water salinity, the Aral region's local population (Kazakhstan and Uzbekistan) face different respiratory problems and accumulation of kidney stones [48]. Metals, such as lead, mercury, and cadmium, are conservated in salt-crust, found at higher levels among this population, leading to anemia [49].

3.3. Biological Weapon Testing Island in the Basin

The ASB has suffered from other activities that took place upstream in the Basin. The Aralsk site, which was constructed on Vozrozhdeniya Island in the basin, which is now abandoned, was at one time known for its biological weapons testing center. The northern part of the island ("Mergensay") now belongs to Kazakhstan [50], while the Southern part of the island belongs to Karakalpakstan, an autonomous republic of Uzbekistan. The test site was developed due to the bio war race between the US, USSR, and the UK in 1952, when the Soviet Union Ministry of Defense commenced the Field Scientific Research Laboratory "PNIL" for biowarfare testing. The island was plagued by infectious diseases such as anthrax, smallpox, plague, tularemia, brucellosis, and typhus tested by the Soviet Union on horses, monkeys, sheep, donkeys, and laboratory animals [51]. This is a consequence of the bio war testing products not being disposed of properly. Consequently, rodents and experimental animals can become conveyors of the above diseases in the future due to external factors such as climate change, the exposed bottom of the Aral Sea and possibly improper disposal of the laboratory [52].

3.4. Aral Desiccation Crisis

The Centre for Health Protection and Ecological Design, under the Ministry of Environmental Protection of the Republic of Kazakhstan, conducted a study on the "Development of Ecological Methods for Health Improvement in the Lake Aral Region" during 2007–2009. According to the study, the residents around the Aral Sea region faced challenges like unemployment, low income, and closure of enterprise due to the Aral disaster. At the same time, the average income per capita has remained at the level of the minimum consumer basket [53,54]. The lack of safe drinking water and unsafe plant products due to contamination of water and soil with arsenic, cadmium, mercury, and lead have exacerbated this situation. This has led to an exodus that caused an increase in agricultural practices by locals in nearby areas, especially in Kyzylorda, Kazakhstan [53,54].

According to investigations, 150 million tons of salts are fed to the Aral Sea, 43 million tons of salts comprising calcium sulphate, calcium bicarbonate, magnesium sulphate, magnesium carbonate, and sodium chloride, nitrates, silicates, ammonium, and iron. These salts do not have significant health effects, but they cause severe health issues [34,36].

The toxic substances mentioned above are accumulated in plants and following the food chain, they reach local animals, being stored in their organs such as kidneys and liver. This, along with the general lack of sanitation, old pipelines, and low water quality [55], worsens the health situation.

4. The Aral Sea and Its Related Health Issues

The exposed bottom of the Aral Sea had a dry salt crust and numerous pollutants. The dust storms carried these contaminated salts and deposited them on land surfaces, reportedly causing several health issues like disability, reproductive and tumors to the people living in the Aral Sea region. Numerous studies conducted by scientists show that the population's state of health in the Aral Sea region has continued to deteriorate in recent decades [56]. The following sections detail the health conditions of the population in the Aral Sea region.

4.1. Respiratory Disorder

The spread of atmospheric air pollution caused by dust storms has led to respiratory diseases such as chronic bronchitis, bronchial asthma, and tuberculosis. Instead, there is a belief that dust storms cause respiratory diseases, several researchers just describe the issue generally, without detail investigations for the case of Kazakhstan [56–59]. Gazizova [60] analyzed retrospective data about respiratory diseases among the adult population of the Aral Sea zone between 1991 and 2016. A growth of respiratory diseases was detected in the catastrophe zone from 9467 diagnosed people (per 100 thousand population) in 1991 to 10,744 (per 100 thousand) in 2016. The number of people with respiratory diseases in the catastrophe zone in 2016 slightly varied with the number of people diseased in the crisis (9247) and pre-crisis (9079) zones. The number of people in the control zone differed significantly—5879 people per 100,000 population. The respiratory and pulmonary functions were studied by researchers [61] among the children at the Catastrophe zone. 8.1% of the surveyed kids in the study area found chronic cough in the study area, compared with 4.6% in the reference area. The study considered subjects from 200 km and 500 km from the Aral Sea. Some investigations have been carried out in neighborhood countries. An annual analysis of asthmatic status in Central Asia found that about 113 per 100,000 people suffered from asthma in the Khorezm region (Uzbekistan), which is more than three times higher than the national average (38 incidences per year 100,000 of the population). In Karakalpakstan, it was 67 per 100,000 people which is twice the national average [62]. Researchers Kunii et al. and Bennion et al. conducted studies in Uzbekistan during 2000 to find the connection between the dust storms and respiratory disorders among the children residing near the Aral Sea [61,63].

The results of these studies show no strong connection between dust storms and respiratory disorders. However, this does not mean that the sandstorms are harmless. Even though no direct connection to respiratory diseases was found, the dust storms could indirectly affect the Aral Sea region's demographics.

4.2. Disabilities

The analysis of the results [64] for the study period 2004–2013 revealed the prevalence of 6 classes of pathology: cardiovascular diseases were perhaps highest, respiratory diseases on the second highest, vision pathologies on the third, and mental disorders were in the fourth most prevalent. The malignant neoplasms followed the rank, with injuries being the last. The disability rate in three zones as compared to the control region is shown in Figure 4 [65]. It can be seen that the incidence rates of respiratory disabilities were highest in the catastrophe zone; cardiovascular and psychological disabilities were peaking in the crisis zone.

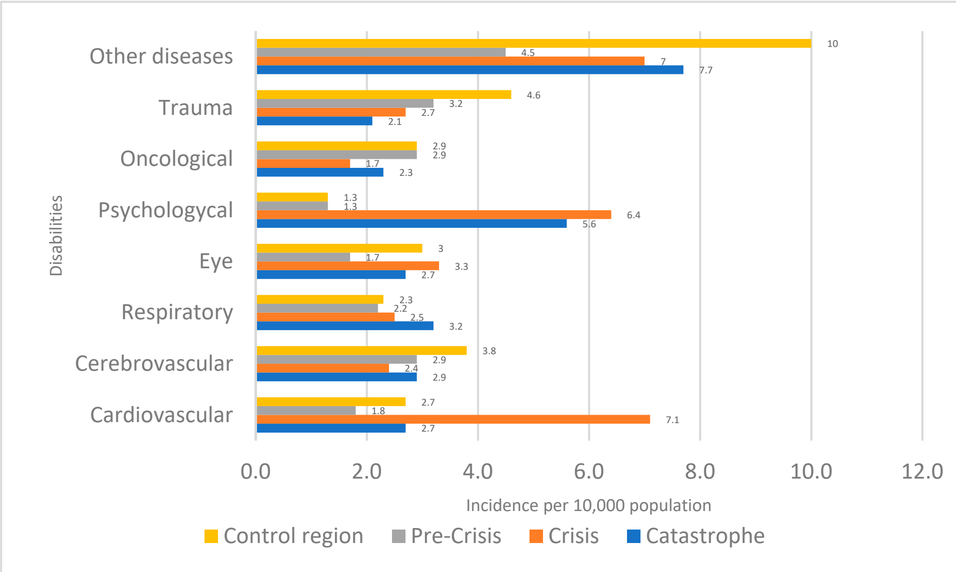

Figure 4. The structure of the primary disability of adults per 10,000 of the population in the Aral Sea region for the years 2004–2013.

The study also calculated the prediction of disability occurrence until 2023 based on the disabilities observed from 2004 to 2013. The predicted incidence of disability for the year 2023 shows a 28.1% increase in the Aral Sea region, 28.4% increase in the Kazalinsk, 7.9% increase in the Shalkar, 46.4% increase in the Karmakshy, 30.9% increase in Zhalagash, 43.7% increase in Arys, 23.1% in Irgyz, and 39.1% increase in Ulytau region. However, this is too rough of an estimation, which does not account for risk factors, the demographic structure of the population, and the curve of the disability distribution. That is why this prediction should be interpreted accordingly.

4.3. Incidence of Cancer

Malignant neoplasm (cancerous tumor) [66] is another health disaster to be considered while analyzing the health effects in the Aral Sea region. To analyze malignant neoplasm incidence, the data of a 10-year (2004–2013) timeframe were considered. The data were reported to be taken from local oncology dispensaries. Figure 5 shows the ten-year average malignant neoplasm incidence in the three disaster zones (catastrophe, crisis and pre-crisis as described in Figure 3), Zhanaarka district, and the whole of the Republic of Kazakhstan for comparison purposes. The incidence rates are calculated for 100,000 populations residing in the regions mentioned above.

The catastrophe and the crisis zones have 61.9% (211.6) and 57.2% (205.4) per 100,000 population increased incidence rate of malignant neoplasm, respectively, when compared to the control region (130.7). The incidence rate in the pre-crisis region is 152.7 for 100,000 population, which is 16.8% higher when compared to the control region but is 18.8% lower than the Republic of Kazakhstan. The detailed observations from individual locations showed the controversial picture.

As discussed previously, the incidence of cancer in the catastrophe zone was notably higher than in the control region. The three districts belonging to the catastrophe zone are Aral, Kazalinsk, and Shalkar. The malignant neoplasm incidents observed in the Aral region were 225.8 per 100,000 population, in Kazalinsk was 200.2 per 100,000 population and in Shalkar, it was 179.9 per 100,000 population. These observations are 1.7, 1.5 and 1.4 times greater, respectively, compared to the control region, Zhanaarka (130.7 per 100,000 population), while the value in Kazakhstan was 188 per 100,000 population.

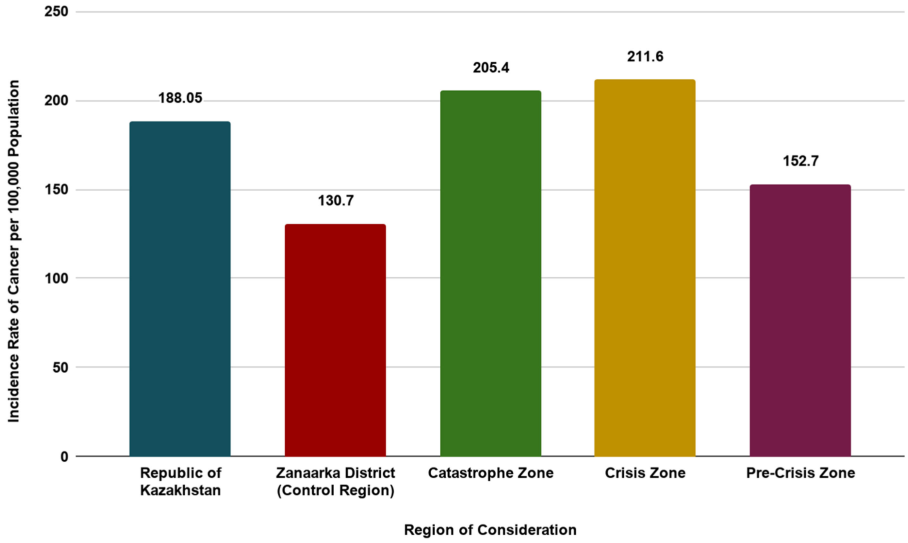

Figure 5. Ten-year annual average of cancer incidence rates 100,000 people for the period 2003–2014 [64].

Similarly, the observations made at the crisis zone are higher than the control region and the Republic of Kazakhstan. The incidence observed in the Zhalagash, Karmakshy, and Shieli regions was 1.65, 1.69 and 1.53 times greater than the control region.

For the pre-crisis zone, which comprises Arys, Irgiz, and Ulytau, the observed cancer incidence was 153.3, 202.2, and 102.6, respectively. Only the Ulytau region has cancer incidence less than the control region. Arys and Irgiz have 1.17 and 1.54 times more than the incidence rates observed in the Zhanaarka region. As for the Ulytau region, the incidence rates observed for the period 2003–2014 were 1.27 times less than the control region and 1.84 times less than the Republic of Kazakhstan.

Another research study [67,68] has collected data on multiple types of cancer that affected the population of the Aral Sea region. These data were collected for 11 years starting from 1999 and lasting until the end of 2009. Figure 5 shows the distribution of types of cancer observed during this time period. A total of 10,382 cancer incidents was recorded. Among these, esophagus cancer is the most prominent with a 17.8% occurrence rate, at second and third positions, lung cancer and cancer of the stomach have a close 12.7% and 12.6% occurrence rates. These forms of cancer were prominent during the 1999 to 2009 period.

4.4. Reproductive System

In the Aral Sea region, it was found that there was a decrease in life expectancy among the demographic indicators along with a high perinatal and infant mortality [69]. Out of the 19,561 mortality cases between 1999–2008 in the Kyzylorda region, 16.1% (3155) were women of reproductive age (15–49 years) [70]. The average annual mortality rate for women in the Kyzylorda region at the fertile age was 1.98 ± 0.05 per 1000 population, decreasing the dynamics for 1999–2008 by 2.15%. High mortality rates of 4.51 ± 0.17 per 1000 population were established in 45–49 years [71]. According to the survey performed on women's reproductive stage in Kazakhstan, the women in the Aral region, compared to other parts of the Soviet region, faced later menarche, menstrual disorders, and spontaneous miscarriages. At the same time, a positive trend in reproductive behavior was observed. The optimal reproductive age was between 20 to 34 years of age, among 88.2% of the laboring population of women. The usage of contraceptives was relatively high for the region (intrauterine device in 32.1%) and the frequency of abortions was low (5.5%) [72].

The onset of pregnancy in most women occurs against a background of irregularities in the hematopoietic, pituitary-thyroid, and immune systems. During pregnancy time, women got affected due to improper intake of nutrition. Meanwhile, babies' immune systems are threatened by lack of breastfeeding because of long-term exposure to pesticides in the Aral Sea region [73–75]. Such compounds accumulate in fetuses through the placenta and breastfeeding in the postnatal period. Hence, we can say that adverse environmental factors and toxicants significantly impact women's reproductive health [76,77].

However, the studies conducted in this discipline are limited, thus making it challenging to draw well-grounded conclusions.

4.5. Psychological Disorder

A psychological disorder is a wide range of conditions that affect an individual's mood, thinking, and behavior. A number of cognitive disorders were revealed in the population of the Aral Sea region, for instance, a decrease in short-term memory, long-term memory and attention span, different psycho-emotional disorders and depression.

During May 1999, a study [78] was conducted to determine the connection between the drying of the Aral Sea and the mental health of the population surrounding it. It was an interview survey involving 118 randomly selected individuals in Karakalpakstan. The survey included a general health questionnaire, Somatic Symptom CheckList-90 (SCL-90, which is a psychometric self-report designed to evaluate a broad range of psychological problems) and questions about the perception of the environmental disaster and social support. 41% of participants reported concerns regarding environmental issues, and 48% reported stages of somatic symptoms connected with mental distress, which was above the standardized cut point; cut-point refers to a mean score above the population norm, signifying a probable case of emotional distress manifested in somatic symptoms [79].

Another research study [80] compared the available clinical records of the Aral zone and Kyzyl-Orda zone in Kazakhstan to understand the mental and behavioral conditions of the population inhabiting the regions mentioned above. It was reported that the Aral zone had about 1.4 times more occurrence of psychological disorders (642.9 cases per 1000 population) than in the Kyzyl-Orda zone in Kazakhstan (451.5 cases per 1000 population).

Psychological disorders observed around the Aral Sea region could be an example of the indirect effects of dust storms. The dust storms deposit harmful chemicals on the fertile soil bringing about a decline in agricultural production. The inhabitants of the region who were dependent on agriculture were now unemployed. Poor economic conditions, unemployment and deteriorating health conditions take a toll. These factors could lead to increased stress and depression. However, these survey-based studies are heavily reliant on the self-assessment of the patient. There is no solid standard to weigh the opinion of a patient. Moreover, these studies are cross-sectional with randomly selected participants; thus, the selection of patients for the study, the socio-economic conditions of the selected population and several other factors act as uncontrollable variables, thus making the result of the study less reliable.

4.6. Nervous System

The role of environmental factors in developing neurodegenerative diseases of the nervous system has been repeatedly emphasized. Recent literature finds the association between the environmental factors and multiple sclerosis [81–83] among the population and Parkinson's disease [84].

The adverse effect of environmental factors is indicated by an increase in central nervous system disorders like mental disorders and decreased intelligence [85]. Highly toxic substances such as lead, nickel and chromium cause asthenia and psychogenic disorders [86]. The prevalence of depressive personality disorders in the Catastrophe zone exceeds that of the Control zone by almost three times, the prevalence of anxiety disorders by 2.5 times and depressive disorders by more than two times.

Nervous disorders are found to be at a relatively very high rate. Almost one in ten of the women surveyed in the crisis zone suffered from nervous system diseases, and the peak of the frequency of these diseases falls between the age of 20–50 years [87–91].

5. Population: Socio-Economic Situation and Changes by the Ecological Situation in Aral Sea Region

The analysis describes that the negative economic trend of the 1990s affected the quality of life of the Aral area population. Moreover, data show that migration and fluctuation can be directly linked to the region's environmental conditions, harsh climatic conditions, and deterioration of the population's health.

5.1. Overview of the Economy of Kazakhstan and the Aral Sea Region

Kazakhstan emerged as an independent state and embarked on its capitalist transformation in challenging circumstances. The Soviet economy from which it emerged was already in free-fall—Soviet GDP (gross domestic product) fell by somewhere between 8% and 17% in real terms in 1991 [92]—and the newly independent Kazakhstan faced enormous economic challenges and state-building in a much broader sense.

During 1992–1995, real GDP fell by an estimated 31%, inflation surged into triple and quadruple digits (annual consumer price inflation did not fall below 100% until 1996), and the labor market witnessed the destruction of 1.6 million jobs [93]. A weak recovery began in 1996–1997, but the impact of the Asian financial crisis of 1997 and the Russian crisis the following year helped to tip the economy back into recession. Growth resumed weakly in 1999 and then began to surge in 2000 as oil prices recovered (Figure 6). From 2000, growth accelerated sharply, reaching an average of 9.4% during 2000–2008. Growth slowed sharply in 2009 before rebounding somewhat until the sharp drop in commodity prices in 2014–2015, which led to a slowdown, with growth falling to 1% in 2016.

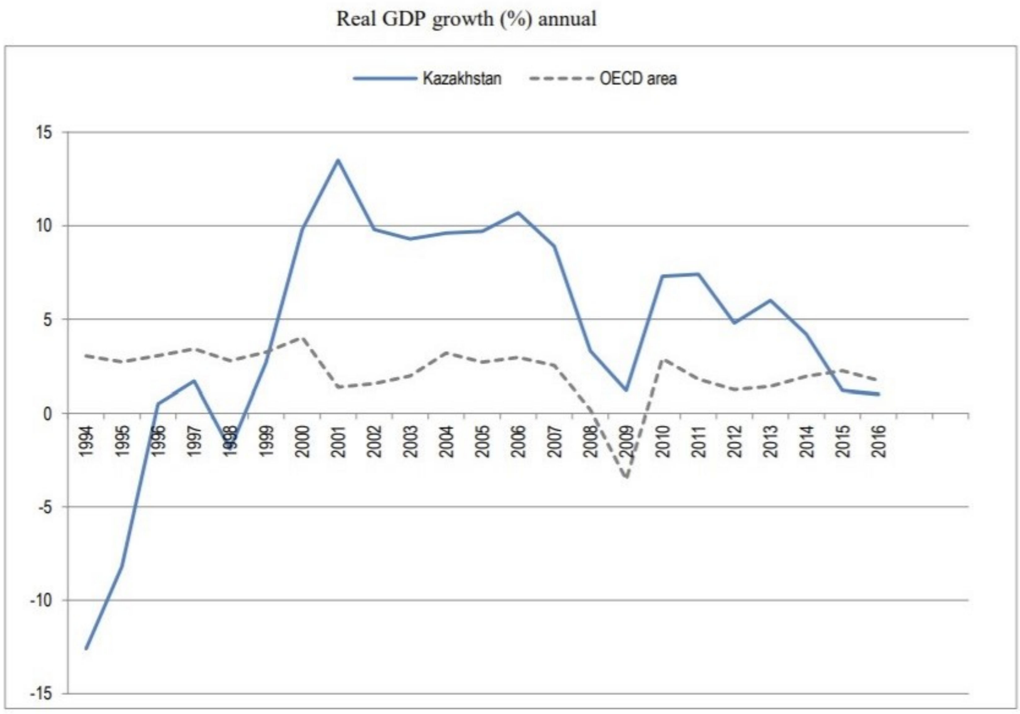

Figure 6. Growth performance, 1994–2016 where OECD is the Organization for Economic Co-operation and Development.

After securing its independence, Kazakhstan faced a major migration crisis. Those processes can be divided into two chronological periods. The first period was in the 1990s, when the European population massively left Kazakhstan. The reason for emigration was that the economic crisis occurred after the collapse of the Soviet Union and followed political reforms (liberalization in socio-economic, political, and other spheres), and the influence of the Asian and Russian financial crises in 1997–1998 (Table 1). The second period was in the beginning of the 2000s; net migration became positive in 2004 and even increased in the following years. After implementing the "Returning ethnic Kazakhs" policy, the volume of immigration among ethnic Kazakhs under the state policy on ethnic return migration increased [94].

Table 1. Calculations based on the data from the Agency of Statistics of the Republic of Kazakhstan.

Indicator	1991	1992	1993	1994	1995	1996	1997	1998	1999
Immigrants (in thou.)	170.8	161.5	111.1	70.4	71.1	53.9	38.1	40.6	41.3
Emigrants (in thou.)	228.5	317.8	330.1	477.1	309.6	229.4	299.5	243.7	164.9
Gross migration (in thou.)	399.3	479.3	441.2	547.5	380.8	283.3	337.5	284.3	206.3
Net migration	−57.7	−156.3	−219.0	−406.7	−238.5	−175.5	−261.4	−203.0	−123.6
−per 1000 inhabitants	−3.5	−9.5	−13.4	−25.2	−15.1	−11.3	−17.0	−13.5	−8.3
Effectiveness index (in %)	−14.4	−32.6	−49.6	−74.3	−62.6	−62.0	−77.4	−71.4	−59.9

The collapse of the Soviet Union in 1991 led to the creation of several new countries with their separate water policies. Lost economic links with other states of regions led to fragmentation of regional water and energy management systems. The weak efforts of newly independent countries to reach an agreement in the water sphere increased the water shortage in the area and worsened the environmental disaster, which led to massive migration. In addition, the drying lakes (Figure 2) had transformed into deserts, followed by changing the original flora with hardier plants. Therefore, the local people lost their workplaces and left their hometowns to achieve better incomes, living conditions and education in more developed regions in Kazakhstan.

5.2. Social and Demographic Situation in Kyzylorda Region (Aral Sea Region)

Desertification and affected by land degradation and desertification in dryland areas on socio-economic conditions can trigger a vicious cycle of poverty, ecological degradation, and forced migration that may further lead to social unrest and/or conflict. Migration and urbanization may worsen living conditions by overcrowding, unemployment, environmental pollution, and the overstressing of natural and infrastructural resources [95].

For Karakalpakstan (Uzbekistan), the Aral Sea crisis impacts on social implications have also been broad, including health effects, increasing outmigration, and economic decline—the secondary impacts of which further threaten to lock the population into a downward spiral and weaken their ability to adapt and cope [95,96].

An analysis of migration patterns in the Aral Sea region showed that the main reasons for the departure of people from one settlement to another were the relocation of rural inhabitants to favorable and promising rural settlements. At the same time, the smallest number of people left in 2008, thus the migration balance was −3 per 1000 population, while in 1991 the migration balance was the highest and amounted to −6.8 per 1000 population. According to the Statistics Department of the Kyzylorda region, the largest number of arrivals and departures occurred in 2019—41.9 and 36.8 thousand people. Accordingly, the smallest number of arrivals and departures occurred in 2015—9.9 and 6.9 per thousand people.

In 2019, the population of the Kyzylorda region was 802.8 thousand people. Meanwhile, the population of the Aral district from the Statistics Committee of 2019 is 79,600 people. (Table 2).

In the Aral Sea region, the largest outflow occurred in 2008, with a migration balance of −156, when 55 people left the village of Zhaksykylysh. Nevertheless, in 2015, 156 people arrived in the same village, and the total number of people in the whole region was positive, with a migration balance of 333. The analyzed area also shows stable growth in the population from 13.6 thousand people in 2005 to 15.5 thousand people in 2015. The most numerous settlements in the Aral region are the village of Zhaksykylysh—more than

5 thousand people, then the village of Amanotkel with 2.5 thousand people and the station Kamystybas with 1.9 thousand people.

Table 2. Socio-demographic data in the Kyzylorda region.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Socio-demographic data											
Population at the end of the year											
Thousand people	689.0	700.5	712.9	726.7	739.7	753.1	765.2	773.1	783.1	794.3	802.818
Total birth rate (per 1000 people)	27.90	28.80	28.40	28.10	26.80	27.30	25.90	25.04	24.39	24.34	24.19
Mortality rate (per 1000 people)	7.20	6.90	6.70	6.60	6.08	6.09	5.72	5.85	5.54	5.45	5.68
Infant mortality rate (per 1000 births)	24.71	22.81	19.30	19.00	14.53	12.51	10.66	9.83	8.63	9.09	9.44
Population growth											
Thousand people	14.2	15.2	15.4	15.5	15.3	16	15.3	14.7	14.7	14.8	13.5
Per 1000 people	20.70	21.90	21.70	21.50	20.80	21.40	20.20	19.19	18.85	18.89	18.51
Migration balance	−3	−3.8	−3	−1.7	−2.2	−2.5	−3.3	−6.7	−4.6	−3.7	−5.1
Arrived (thousand people)	11.5	11.9	11.8	11.8	10.6	13.1	15.3	21.6	30.3	31.7	36.8
Retired, thousand people	14.4	15.7	14.8	13.5	12.8	15.6	18.6	28.3	34.9	35.4	41.9

The population in the period from 2005 to 2015 remained relatively stable and held at around 15,000 people in research settlements (Table S1). If between 2005 and 2008 there was a little outflow with migration balance −33 and −55, respectively, then in 2011 the population is slightly growing. Authors suppose that the main reason for economic stability is the building of the Kokaral dam. Despite the environmental crisis-affected the region, we can observe a clear trend of stable population growth at the present stage. The birth rate, which peaked in 2010 (28.8 per thousand people), has begun to decline slightly, although it has remained stable at a high level of about 24 per 1000 people, and the mortality rate tends to decrease from 7.2 (2009) to 5.68 (2019) per thousand people.

According to 2019 data, the economically active population in rural areas is 348.2 per thousand people, including 331.7 thousand people employed, of which 114.2 thousand people are self-employed. Compared to the respective period last year, the total population in rural areas decreased by 14,364 people or 3.5%; the economically active population decreased by 7149 people or 3.5%; the employed population by 3182 people, or 1.7%, including the number of self-employed people increased by 4234 people or 5.2%. (Table 3). In percentage terms, whereas in 2005 the number of unemployed in Kyzylorda region was 4.7%, in 2008 the figure fell to 3.1%, then there was a slight increase in the number of unemployed to 3.4% in 2018.

Table 3. Average per capita nominal monetary income of the population in the Aral district of Kyzylorda region, in tenge. Department of Statistics of Kyzylorda region.

Labor Market and Wages	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Labor force (aged 15 and over)											
Thousand	307.4	317.4	337.5	347.6	352.6	327.6	325.213	345.6	347.4	349.7	348.219
Employed											
Thousand	165.6	176.9	197.1	219.6	224.5	222.3	198.313	206.9	214.2	218.2	217.519
Self-employed											
Thousand	121.4	121.8	121.8	109.5	109.8	88.9	110.613	121.6	116.4	114.7	114.219
Unemployed											
Thousand	20.4	18.7	18.6	18.5	18.3	16.4	16.213	17.0	16.8	16.8	16.619
Unemployment rate in %	6.6	5.9	5.5	5.3	5.2	5.0	5.013	4.9	4.8	4.8	-

Per capita income in the Aral district remains the lowest in the region. The population living below the poverty line is about 44% and the official unemployment rate is over 7%.

As a result of the decline in the incomes of the rural population of the Aral Sea region, the problem of their standard of living has become the main focus of attention. Moreover, between 2005 and 2015, there has been a gradual decline in the proportion of the population with incomes below the subsistence minimum, which was about 2%.

Additionally, one of the authors conducted a random interview, it turned out that there was a significant level of adaptation of the local population to environmental conditions. Thus, we can conclude that the situation in the Aral Sea region is slowly but steadily stabilizing. The interviewed respondents do not complain about their health, have a permanent job, and additional payments from the state.

Moreover, local residents do not express their desire to leave their place of residence—according to the survey, 70.4% of respondents do not plan to move in the next five years. The authors initially associated the cause of population migration with changes in the region's environment, adversely affecting the population's health. Still, the survey results do not confirm this fact, and the authors consider that this fact is more likely connected to the various social benefits [23] for the population living in environmental crisis zones. People tend to live in the Aral region rather than leave it. Local residents associate migration mainly with obtaining higher education, having a job in their specialty in other regions, and a more prosperous environment in other settlements.

Yet, the reason for staying of environmental migrants could be poverty, linking the individual to his/her ethnic group or religious community, land grabbing, communication technology and diasporic, and fear of contamination by unknown diseases. These migrants have to undergo a complicated and often conflictive integration process in the hosting community. From a health standpoint, newly arrived migrants are primarily healthy (healthy migrant effect), but they may harbor latent infections that need appropriate screening policies [96].

Despite the environmental crisis, people from other settlements move to this area. The authors consider that there should be in-depth research on whether the social benefits programs motivated them to stay and move to ASB.

The authors suppose that relative stability can be linked to the building of Kok-Aral dam. As a result of its construction, since August 2005, the outflow has been controlled by a discharge structure (gates) in the dam. When the water gates are open at the Kok-Aral dam and there is heavy outflow, all the remaining southern water bodies of the Aral Sea are connected for a period of time [30]. Local people call this dam "Dam of life". The Kok-Aral dam has allowed an increase of the water level in the Small (Northern) Aral Sea in 6 months to +42 m a.s.l., and with "forcing" to 42.5 m [97]. The present average salinity in the Small (Northern) Aral Sea is less than 10 g/L [58]; it will decrease even more in the near future.

6. One Health Concept—An Approach for Improved Public and Environmental Health in ASB

Massive water withdrawals coupled with continuous water contamination from the industry and agriculture have led to shrinking the Aral Sea and polluting the water resulting in the dried bottom of the lake and formation of the salt crusts. In turn, contaminated salt crusts spread by the dust storms and polluting the surroundings adversely affect people's health. However, most of the studies undertaken are observational studies and fail to provide a scientific rationale to explain the relationship between the drying lake and observed health effects around it. Even though the water is not shrunk, the number of pollutants collected in the sea would have been accumulated in the fish and subsequently would affect people's health sooner or later. This clearly shows the lack of integration between environmental, hydrology, agriculture, public health, and other related experts. Considering the outcome of people's health, the health of the environment, and the health of animals/fish, integrating a One Health approach in the work of experts would strengthen the outcome for both the health of people and the health of the environment. The role of local authorities, especially in healthcare, should be underpinned in implementing the

One Health approach, which considers joint efforts and establishes strong communication among all the relevant stakeholders, including experts.

In the current crisis situation in the Aral Sea region, we can observe many factors attributed to the One Health approach (Figure 7). Firstly, the main reason for the drying up of the Aral Sea was a significant increase in population and intensive land development for agricultural needs without considering environmental consequences. This now affects continued security as well. Secondly, the ecological crisis caused by the drying up of the sea has led to a change in the operating environment, desertification, and a change in the region's landscape. Thirdly, the environmental crisis directly affected the quality of life of the region's residents by affecting their health and contributed to population migration. Fourthly, the Vozrozhdeniye Island is no longer an island, so the biological weapons test site is not isolated and is therefore accessible to humans and animals. The long-term consequences of this problem are difficult to predict.

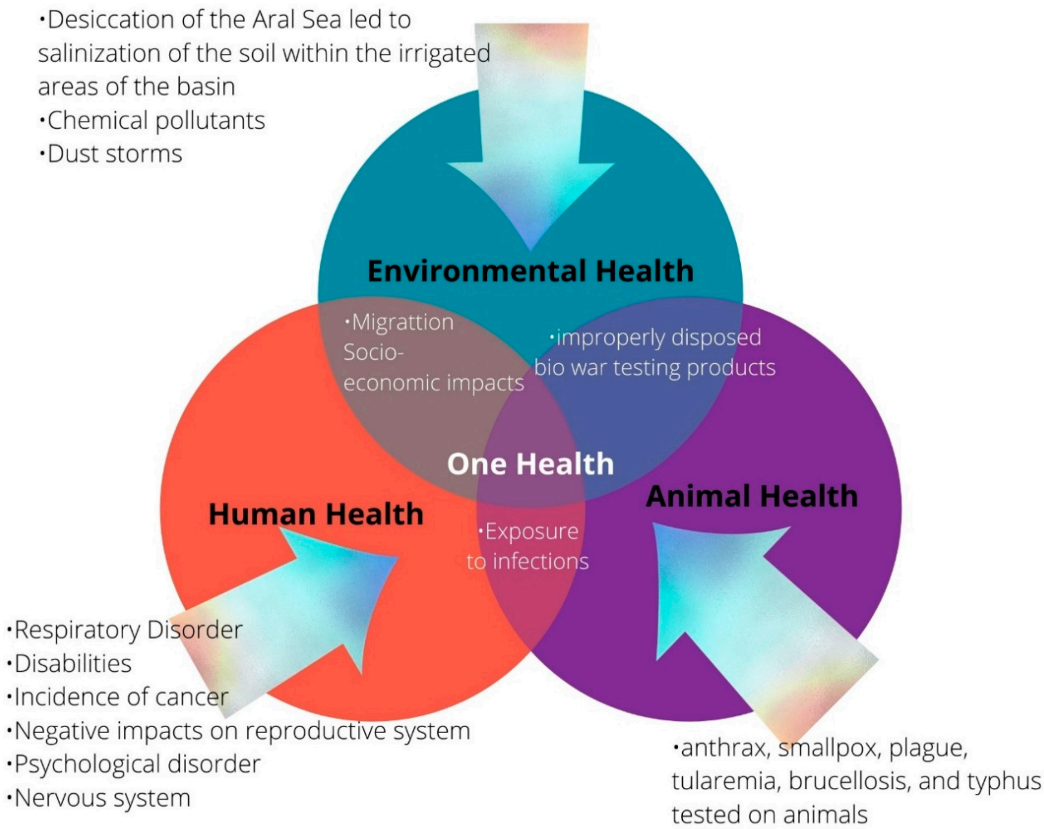

Figure 7. One Health concept adaptation by the authors.

All these factors are interconnected and require an integrated approach for the solution. In this situation, the use of the One Health approach creates the possibility of a comprehensive solution to the region's problems.

Therefore, to successfully combine them, a well-coordinated approach in humans and animals is necessary.

7. Discussion

Several studies were conducted to find the impacts of declining water levels in the Aral Sea and the deteriorating health condition of the surrounding population. This paper centers on studies conducted on six of the major health conditions observed in the population around the Aral Sea. Moreover, some of the authors conducted their research in the frames of one of the aspects, for example environmental health, shrinkage of the Aral Sea and its negative effects, the chronology of the drying lakes in the regions, etc.

Numerous studies hypothesize the adverse effects of the drying of the Aral Sea on human health. A majority of the claims are centered around dust storms causing respiratory, psychological, and other disabilities observed in the Aral Sea region. However, despite the mentioned ecological impacts of the Aral Sea on the health of the people, the general indicators of health, mortality rate, and birth rate correspond to the indicators in the Kyzylorda region, even in the places that were not affected by this Aral crisis.

The study conducted on lung conditions of the children living in the concerned areas in 2000 revealed no evidence of respiratory disease symptoms among them [61,98]. Other health issues were related to the nutrition and food habits of the population. Prevailing poverty resulted in women and infant morbidity due to malnutrition. The residents around the Aral region faced challenges like unemployment, low incomes, and enterprise closure due to the Aral disaster [99]. This might have led to an increase in local agricultural practices for sustenance. Negligent agricultural practices heavily relied on chemical fertilizers and pesticides contained in the soil and water. An unrestrained discharge of industrial pollutants into the lake aggravated the environmental situation. Heavy metals, chemical pollutants, persistent organic pollutants (POPs), chemical fertilizers such as DDT and PCB, and other pollutants have been found in the food chain and in the bodies of the population living around the Aral Sea. Biowarfare testing in the area and radioactive mineral mining could have also contributed to deteriorating health conditions [100,101]. Studies show the connection between these pollutants and health issues. These pollutants probably caused high rates of malignant neoplasm and the discussed disabilities.

Studies conducted in this domain are mainly cross-sectional, and some are case-controlled. These studies have several uncontrollable variables that make the results less reliable. Additionally, there is a lack of long-term longitudinal studies in the region. Another issue is information mismatch [102] between official data and the observed data. However, there is not enough evidence to confirm this claim. The majority of the research was conducted during the 1990s and early 2000s. A decrease in research in recent years has been observed. Despite multiple evaluations, there seem to be no well-grounded results to either accept or reject the hypothesis of adverse health effects due to the drying of the Aral Sea. These studies also tend to be region-specific and cannot be applied to a general case of a drying lake.

Environmental stressors may directly or indirectly affect the health of people. People are exposed to economic damage and high adaptation costs during or after major environmental disaster events. Thus, any anthropogenic ecological invasion leads to socio-economic issues. For example, in China, the implementation of big hydropower projects led to the displacement of more than twelve million people, which resulted in assimilation conflicts [103]. Environmental degradation of water resources resulted in severe poverty in the fisheries community in Vietnam [104]. The reduction of regional development, increased unemployment, decreased standards for living, including environment and health, is associated with environmental catastrophe. Consequently, socio-economic problems are directly linked with a higher prevalence of depression [105]. From that perspective, it can concluded that the problem of the drying of the Aral Sea with high probability became a reason for socio-economic issues such as unemployment and it consequently may affect the psychological health of people by contributing to depression and apathy.

8. Conclusions

While the dust storms spread the polluted salts from the exposed bottom across the Aral Sea region, the health issues are caused primarily by the specific contaminants rather than drying the Aral Sea. There is no clear evidence that associated dust storms are the only primary source of deterioration of people's health in the region. Thus, retrospective longitudinal studies and in-depth cross-sectional studies on impacts of environmental, socio-economic factors, and lifestyle on people's health must be performed to better understand water-related reasons for the health issues in the region. The case of Aral Sea could be an excellent example of implementation (or not processed implementation) of the

One Health approach. If the key authorities could aim to achieve better outcomes in the health of the whole ecosystem, including people, aquatic fauna, and the environment, the mismanagement decisions of the Aral Sea region could be avoided. Thus, the One Health approach seems to play a crucial role in the decisions related to environmental invasion. In this regard, the One Health approach is a suitable interdisciplinary tool for solving interrelated environmental problems and the quality of life of the region's inhabitants.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/w13223196/s1, Table S1: Overview of statistics in the settlements of Aral Sea region (2005–2015).

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