BULLETIN OF NATIONAL ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
ISSN 1991-3494
Volume 2, Number 372 (2018), 149 – 157

UDC 528.71: 629

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THE POTENTIAL METHODS OF ANALYSING REMOTE SENSING DATA OF WATER SOURCES IN ALMATY PROVINCE

Abstract. The potential factors that have significance for remote sensing of water resources in Almaty province are described in the article. In this work the algorithm that can be used to correct new developed methods to analyze remote sensing data is described.The research target is to find out whether any factors should be considered as significant during the process of remote sensing of water resources.The research methodologyis based upon epistemology and deduction.The practical research significance is defining the atmospheric process correction algorithm for remote sensing of water sources in Almaty province. The research resultsdefine that the source of the light which was collected as data during the process of remote sensing has the significance not only for information collection but also for data analysis.

Keywords: remote sensing of water resources, remote sensing algorithms, radiance, reflectance, atmospheric processes, the total scattering coefficient, water sources in Almaty province.

The presence of water resources plays the significant role in agriculture [1]. Moreover, absence and poor supply of water are becoming more and more serious issues [2]. The figure below shows reasons which may explain why water supply has become an issue in the certain parts of the world.

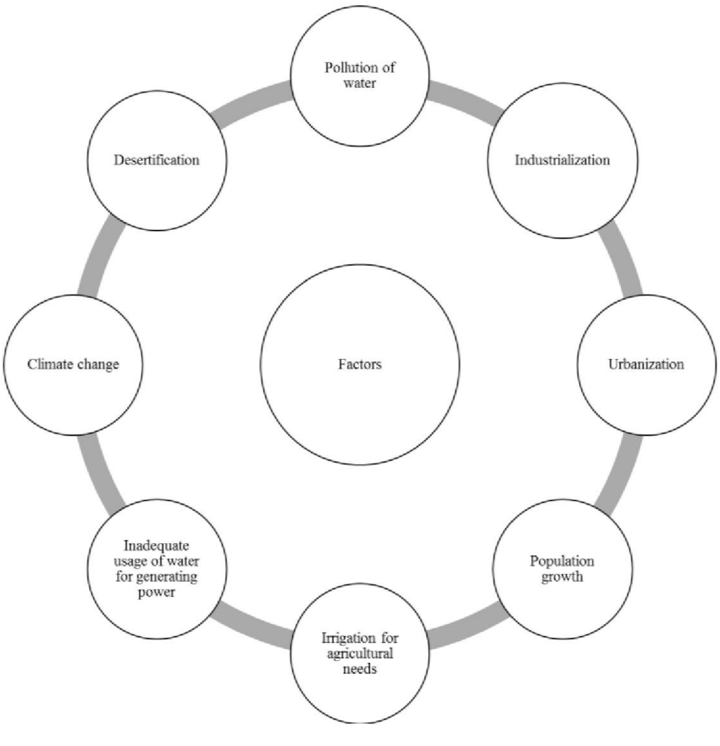

Figure 1 – Factors which impact shortage of water supply in the certain parts of the world.

Note: from the sources 3-7.

The figure above shows that water pollution is one of the reasons which generates less available drinkable water for population and less clean water for agriculture [3, 4]. Moreover, thegrowth of the population in the recent years has created pressure on water supply. In addition, focus on economic development above nature protection interests in developing countries does not help to improve the situation with water supply [5]. Climate change and desertification are among factors which have both natural and anthropogenic origins [6, 7]. As a result, one of the aspects of protecting water resources is maintaining water quality. The table below shows some examples of algorithms for remote sensing to identify water quality.

The algorithms for remote sensing of water resources in Almaty province

Algorithm	*Type*	*Result equation(s)*	*Band ratio (R), coefficients (a)*
Global processing (GPs)	Power	$C_{13}=10(a0+a1*R1)$ $C_{23}=10(a2+a3*R1)$ $[C+P]=C_{13}$; if C_{13} and $C_{23}>1.5\ \mu g\ L^{-1}$ then $[C+P]=C_{23}$	$R1=\log(L_wn443/L_wn550)$ $R2=\log(L_wn520/L_wn550)$ $a=[0.053, -1.705, 0.522, -2.440]$
Clark three band	Power	$[C+P]=10(a0+a1*R)$	$R=\log((L_wn443+L_wn520)/L_wn550)$ $a=[0.745, -2.252]$
K Algorithm	Multiple regression	$\kappa(490)=a_1+a_2{}^*R^{a_3}$ $\kappa(520)=b_2+b_2{}^*R^{b_3}$	$R=L_w(443)/L_w(555)$ $a=[0.022, 0.0883, -1.491]$ $b=[0.44, 0.0663, -1.398]$
Aiken-C	Hyperbolic + power	$C_{21}=\exp(a0+a1*\ln R)$ $C_{23}=(R+a2)/(a3+a4*R)$ $C=C_{21}$; if $C<2.0\mu g\ L^{-1}$ then $C=C_{23}$	$R=L_wn490/L_wn555$ $a=[0.464, -1.989, -5.29, 0.719, -4.$
Aiken-P	Hyperbolic + power	$C_{22}=\exp(a0+a1*\ln R)$ $C_{24}=(R+a2)/(a3+a4*R)$ $[C+P]=C_{22}$ if $[C+P]<2.0\mu g\ L^{-1}$ then $[C+P]=C_{24}$	$R=L_wn490/L_wn555$ $a=[0.696, -2.085, -5.29, 0.592, -3.$
OCTS-C	Power	$C=10^{(a0+a1*R)}$	$R=\log((L_wn520+L_wn565)/L_wn490)$ $a=[-0.55006, 3.497]$
OCTS-P	Multiple regression	$[C+P]=10^{(a0+a1*R1+a2*R2)}$	$R1=\log(L_wn443/L_wn520)$ $R2=\log(L_wn490/L_wn520)$ $a=[0.19535, -2.079, -3.497]$
POLDER	Cubic	$C=10^{(a0+a1*R+a2*R^2+a3*R^3)}$	$R=\log(R_{rs}443/R_{rs}565)$ $a=[0.438, -2.114, 0.916, -0.851]$
CalCOFI 2 band linear	Power	$C=10^{(a0+a1*R)}$	$R=\log(R_{rs}490/R_{rs}555)$ $a=[0.444, -2.431]$
CalCOFI 2 band cubic	Cubic	$C=10^{(a0+a1*R+a2*R^2+a3*R^3)}$	$R=\log(R_{rs}490/R_{rs}555)$ $a=[0.450, -2.860, 0.996, -0.3674]$
CalCOFI 3 band	Multiple regression	$C=\exp(a0+a1*R1+a2*R2)$	$R1=\log(R_{rs}490/R_{rs}555)$ $R2=\log(R_{rs}510/R_{rs}555)$ $a=[1.025, -1.622, -1.238]$
CalCOFI 4 band	Multiple regression	$C=\exp(a0+a1*R1+a2*R2)$	$R1=\log(R_{rs}443/R_{rs}555)$ $R2=\log(R_{rs}412/R_{rs}510)$ $a=[0.753, -2.583, 1.389]$
Morel-1	Power	$C=10(a0+a1*R)$	$R=\log(R_{rs}443/R_{rs}555)$ $a=[0.2492, -1.768]$
Morel-2	Power	$C=\exp^{(a0+a1*R1)}$	$R=\log(R_{rs}490/R_{rs}555)$ $a=[1.077835, -2.542605]$
Morel-3	Cubic	$C=10^{(a0+a1*R+a2*R^2+a3*R^3)}$	$R=\log(R_{rs}443/R_{rs}555)$ $a=[0.20766, -1.82878, 0.75885, -0.73979]$
Morel-4	Cubic	$C=10^{(a0+a1*R+a2*R^2+a3*R^3)}$	$R=\log(R_{rs}490/R_{rs}555)$ $a=[1.03117, -2.40134, 0.3219897, -0.291066]$
OC4	Fourth-order	$Chl-a=10^{(a0+a1*R+a2*R^2+a3*R^3+a4*R^4)}$	$R=max(R_{rs}443, R_{rs}490, R_{rs}510)/R_{rs}55$ $[a0, a1, a2, a3, a4]=[0.366, -3.067, 1$ $0.649, -1.532]$
OCI		$OCI=Chl_{CI}$ [for $Chl_{CI}\leq 0.25\ mg\ m^{-3}$] $OCI=Chl_{OC4}$ [for $Chl_{CI}>0.3\ mg\ m^{-3}$] $OCI=\alpha\times Chl_{OC4}+\beta\times Chl_{CI}$ [for $0.25<Chl_{CI}\leq 0.3\ mg\ m^{-3}$]	$Chl_{CI}=10-0.1909+191.6590*CI$ $CI\approx R_{rs}(555)-0.5(R_{rs}(443)+R_{rs}(670))$

Note: from the sources 8-17.

Abbreviations: 1. C – Chlorophyll concentration (mg m^{-3}). 2. a – Absorption coefficient. 4. c – Beam attenuation coefficient.
3. b – Total scattering coefficient. 5. L_{wc} – White Cap signal.

The figure above shows that the empirical algorithms can be used to identify chlorophyll concentration related aspects of water surface which may indicate some aspects of theecological state of water resources [18, 19].

Another aspect to consider is that water reflectance has animpact on assessing techniques that should be used onanalyzing data collected through remote sensing [20]. The formula below shows links between inherent optical properties (IPO) and reflectance from remote sensing:

$$R_{rs} = \frac{L_w(\lambda)}{E_d} \approx \sum_{i=1}^{2} g_i \left(\frac{b_b}{a+b_b}\right)^i \quad (1)$$

Note: from the source 21.

Abbreviations: 1. R_{rs} – Above – surface remote sensing reflectance (Sr^{-1}). 2. L_w – Water – leaving radiance. 3. E_d – Downwelling irradiance just above the water surface ($W\,m^{-2}\,nm^{-1}$). 4. a - The total absorption coefficient. 5. b_b - The backscattering coefficient. 6. $a + b_b$ - The attenuation coefficient. 7. $g_1 \approx 0.0949I$. 8. $g_2 = 0.0794I$.

Around 90% of theinformation for remote sensing of water reflectance properties for many projects often come from scattering the atmospheric layers [21]. Therefore, another factor to consider is the impact of how sunlight may be scattered through different layers of atmosphere [22].

On the other hand, its impact can be ignored if water-leaving radiance is taken into account which formula is shown below:

$$L_u = L_w + p_f \times L_{sky} + L_{wc} + L_g \quad (2)$$

Note: from the source 23.

Abbreviations: 1. L_u – The radiance which was collected by the sensor during remote sensing. 2. L_w – Water – leaving radiance. 3. $p_f \times L_{sky}$ - The sky radiance signal which reflected from the water surface and entered the sensor. 4. L_{wc} – The whitecap signal. 5. L_g – The signal of direct sunlight reflected by the surface waves. 6. p_f – Fresnel reflectance of the water surface.

L_{wc} and L_g are assumed to be random due to not having water signals [24]. Moreover, p_f of thewater surface in the calm state is assumed to be equal to 0.0022 [25].

The figure below illustrates origins of light that can be received during the process of remote sensing of water resources.

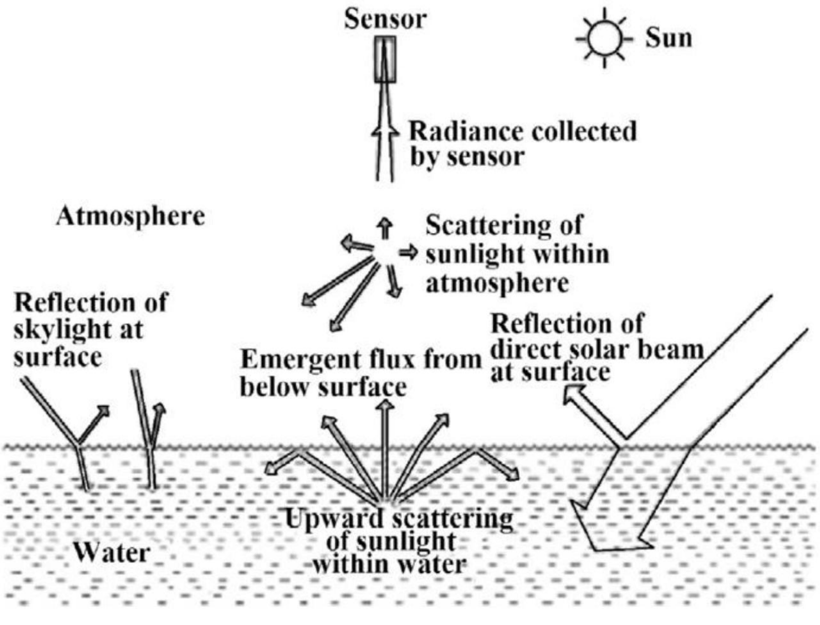

Figure 2 – Different sources of light that can be captured through remote sensing of water sources in Almaty province.

Note: from the source 24.

The figure above tries to model observation geometry for different light origins. However, this raises the question of the total scattering coefficient which formula is shown below:

$$b = c - a \tag{3}$$

Note: from the source 25.

Abbreviations: 1. b – The total scattering coefficient. 2. c – The beam attenuation coefficient. 3. a – The absorption coefficient.

Absorption of different water components plays the significant role in defining the current ecologic state of the water source [26]. However, the figure above also raises the question about remotely sensed radiance which was defined by the formula 1.

On the other hand, downwelling irradiance just above the water surface is defined by the formula below:

$$E_d(0^+) = \pi \frac{L_d(\lambda)}{\rho_p} \tag{4}$$

Note: from the source 27.

Abbreviations: 1. E_d – Downwelling irradiance just above the water surface ($W\ m^{-2}\ nm^{-1}$). 2. $L_d(\lambda)$ – The downwelling radiance spectrum. 3. ρ_p – The reflectance of reference plaque.

If the spectroradiometer is positioned on a boat or ship, then preferable angle of positioning is between 90 to 135° [28]. Combining remote sensing with collecting date from a ship may give the best combination for data collection [29].

The figure below shows which parameters of water can be accepted as optical properties for remote sensing.

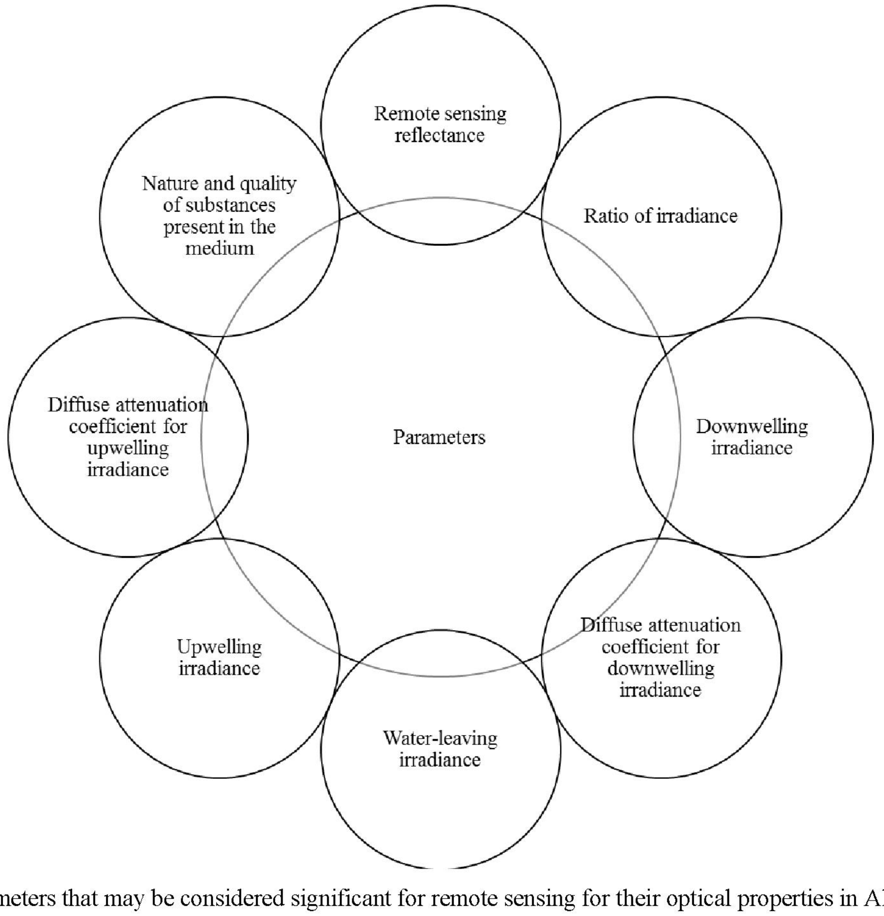

Figure 3 – Parameters that may be considered significant for remote sensing for their optical properties in Almaty province.

Note: from the sources 30-31.

The figure above shows that reflectance plays significant role in analysing data from the remote sensing [32]. However, an atmospheric correction of its formula by taking into account its impact into reflection is more accurate way of measurement which is shown by the formula below:

$$L_t(\lambda) = L_r(\lambda) + L_a(\lambda) + L_{ra}(\lambda) + T(\lambda)L_g(\lambda) + L_b(\lambda) + t(\lambda)L_f(\lambda) + t(\lambda)(1 - w)L_w(\lambda) \quad (5)$$

Note: from the source 32.

Abbreviations: 1. $L_t(\lambda)$ – The total radiance received by the sensor during remote sensing. 2. $L_r(\lambda)$ – Rayleigh scattering radiance. 3. $L_{ra}(\lambda)$ – The aerosol scattering radiance. 4. $L_g(\lambda)$ - The contribution arising from specular reflection of direct sunlight from the water surface. 5. $T(\lambda)$ which is standing in front of $L_g(\lambda)$ - The direct transmittance of the atmosphere or beam transmittance. 6. $L_b(\lambda)$ - The radiance from the bottom of the water. 7. $t(\lambda)$ which is standing in front of $L_f(\lambda)$ - The contribution arising from sunlight and skylight reflecting from individual whitecaps on the sea surface. 8. $L_w(\lambda)$ - the reflectance of the water column, or the water-leaving radiance. 9. $t(\lambda)$ which is standing in front of (1-w) - The diffuse transmittance of the atmosphere, which is the attenuation coefficient of the atmospheric transmission between the satellite and the water surface. 10. w - The rate of area covered by whitecaps.

L_r generates nearly 80% of radiance during remote sensing which makes it the most significant component during the process of the atmospheric correction [33].

L_{ra}as a factor has the significance due to aerosol scattering being the second component by size in the atmospheric correction [34].

On the other hand, the direct relationship between reflectance and radiance is shown below:

$$\rho = \frac{\pi L}{F_0 \cos\theta_0} \quad (6)$$

Note: from the source 35.

Abbreviations: 1. ρ - The total reflectance which was received by the sensor. 2. L – Radiance. 3. F_0 - The extraterrestrial solar irradiance. 4. θ_0 - The solar zenith angle.

Rayleigh scattering reflectance is another factor which may need correction shown by the formula below:

$$R_{rc,\lambda} = \pi L_{t,\lambda}{}^{*} \,/\, F_0\cos\theta_0 - R_{r,\lambda} \quad (7)$$

Note: from the source 36.

Abbreviations: 1. $R_{rc,\lambda}$ – The Rayleigh corrected scattering reflectance. 2. λ – The wavelength of the satellite sensor spectral band. 3. L_t* - The calibrated at-sensor radiance after correction for gaseous absorption. 4. F_0 - The extraterrestrial solar irradiance. 5. θ_0 - The solar zenith angle. 6. R_r – The reflectance due to Rayleigh (molecular) scattering estimated using the 6S radiative transfer code.

The flowchart of atmospheric correction process is shown in the figure below (figure 4).

The figure above shows that NIR wavelength plays the significant role in the remote sensing process of water resources because the following chemical components are visible at NIR [38]:

- CO;
- N_2O;
- CH_4;
- CO_2.

The mechanism of remote sensing of the water source in Almaty province is shown in the figure below (figure 5).

The figure above shows that the following sources of lights which leave the water surface are going to be caught during the remote sensing of lakes, rivers or other water reservoirs in Almaty province:

- upward scattering from water molecules, suspended materials that are inorganic, phytoplankton;
- scattering from sunlight which comes from the bottom;
- absorption yellow substance component.

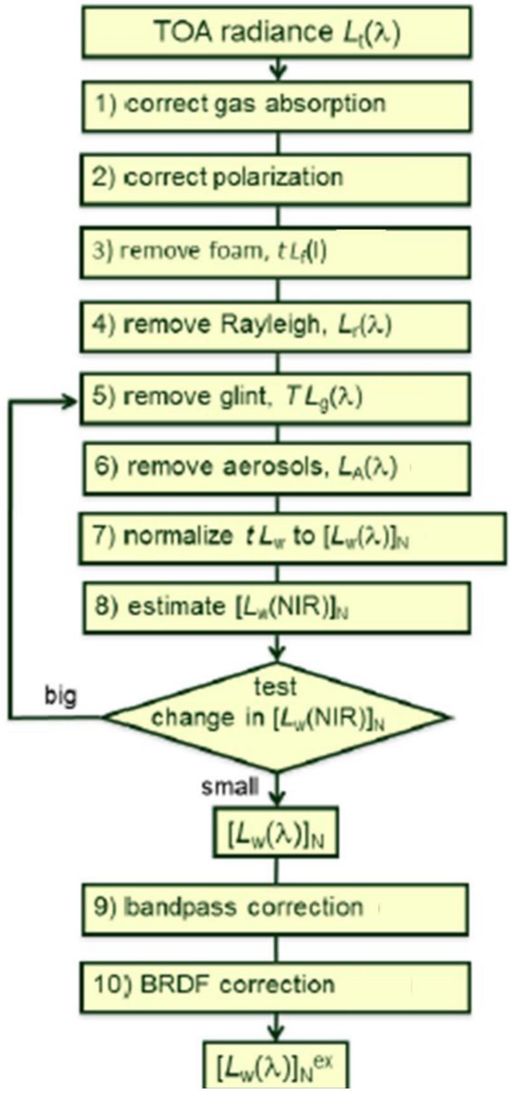

Figure 4 – The atmospheric process correction algorithm for remote sensing of water sources in Almaty province.

Note: from the source 37.

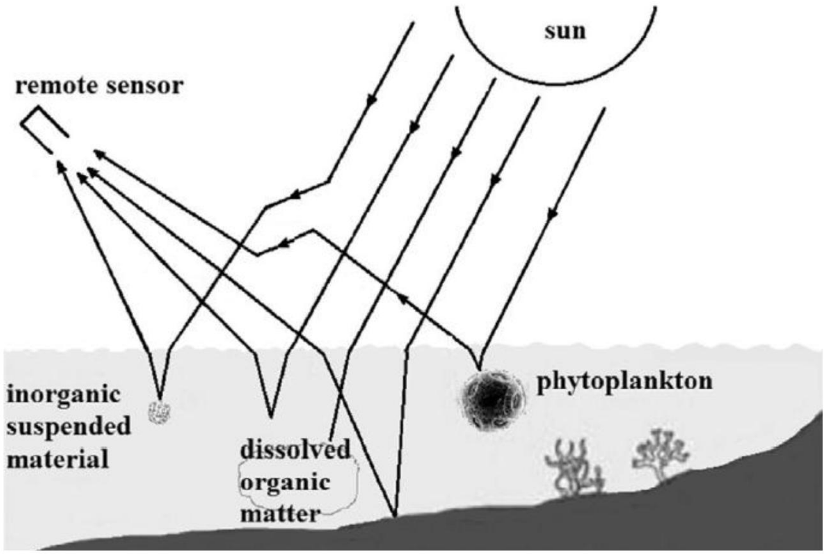

Figure 5 – Factors that have the significant impact on data about light leaving water surface during remote sensing of the water resources in Almaty province.

Note: from the source 39.

The figure above shows that the absorption of yellow substance has the significance upon the amount and quality of light leaving the water surface [40]. The relationship between the absorption component and water-leaving radiance is shown by the formula below.

$$a = a_w + Ca_c{}^* + Xa_X{}^* + Ya_Y{}^* \quad (8)$$

Note: from the source 41.

Abbreviations: 1. a - The water-leaving radiance. 2. a_w – The absorption coefficient of pure water. 3. C - Chl-a concentration (mg m^{-3}). 4. a_c*- The chlorophyll-specific absorption coefficient. 5. X – The suspended sediment concentration. 6. a_X* - The specific absorption coefficients of suspended sediment. 7. Y – The concentration of colored dissolved organic matter (CDOM) (m^{-1}). 8. a_Y* - The specific absorption coefficients of suspended sediment in the form of colored dissolved organic matter (CDOM).

The value of X is often defined at λ = 550 nm [41].

The figure below shows the factors that have aconsiderable impact on optical properties of water.

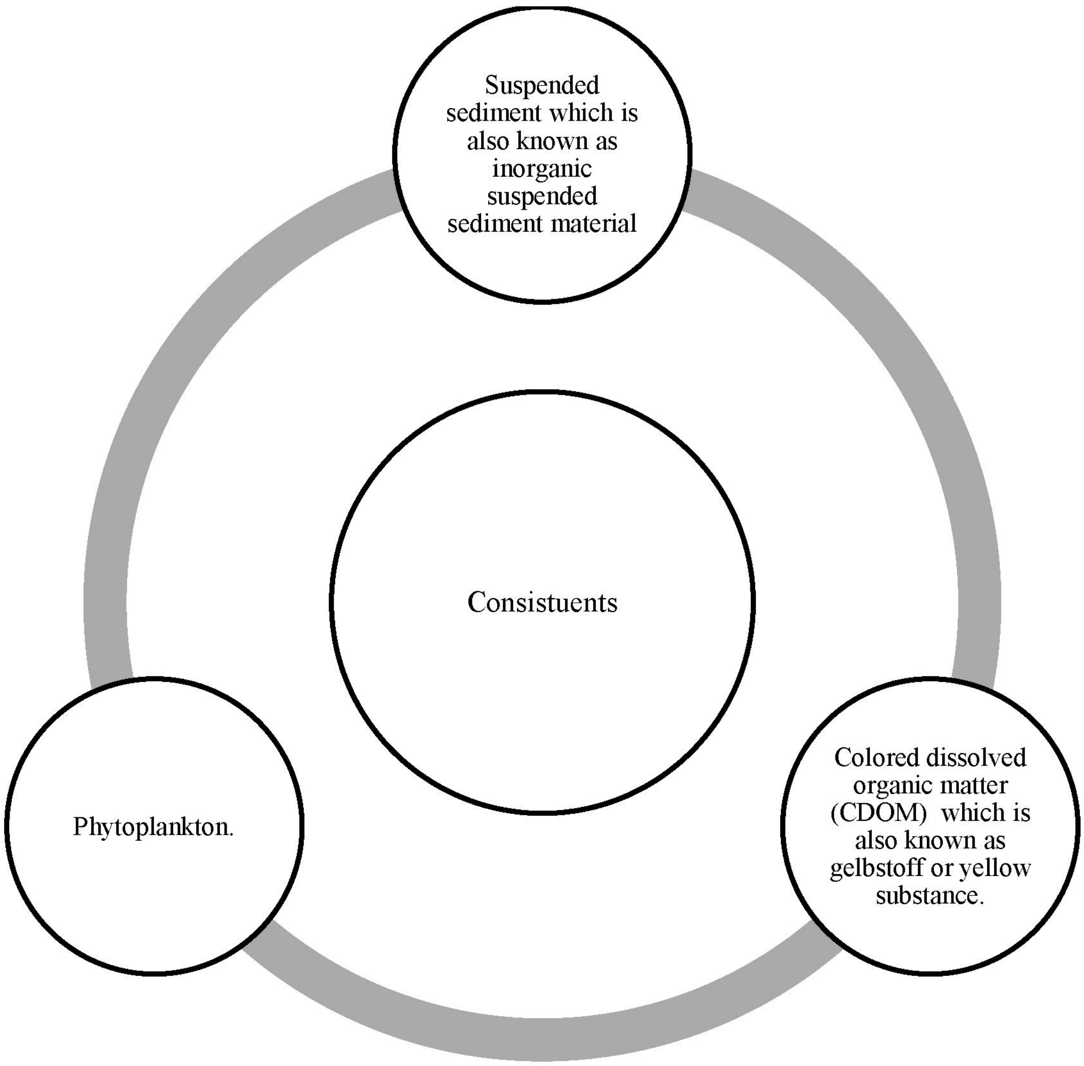

Figure 6 – Constituents which impact on optical properties of water sources in Almaty province.

Note: from the source 42.

The figure above defines that optical properties of water which impact the process of remote sensing for water sources in Almaty province are phytoplankton, CDOM and suspended sediment.

In conclusion, the source of light, water optical properties and atmospheric processes have huge impact on remote sensing of water sources for remote sensing of water reservoirs in Almaty province. Therefore, there is the need for the atmospheric process correction algorithm for remote sensing of water sources in Almaty province which is illustrated by figure 4.

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АЛМАТЫ ОБЛЫСЫНДА СУ КӨЗДЕРІН АРА ҚАШЫҚТЫҚТАН БАҚЫЛАУ МӘЛІМЕТТЕРІН ТАЛДАУ ДӘДІСТЕРІНІҢ МҮМКІНДІКТЕРІ

Аннотоция. Мақалада Алматы облысындағы су көздерін ара қашықтықтан бақылаудағы факторлардың әлеуетінің маңыздылығы жазылған. Бұл жұмыста ара қашықтықтан бақылау мәліметтерін талдаудағы жасалған жаңа әдістерді түзетудің алгоритмі келтірілген. Зерттеудің міндеті – су көздерін ара қашықтықтан бақылау үрдісінде қандай факторлардың маңызды болуының тиістілігін анықтау. Зерттеудің методологиясы эпистомология және дедукцияға негізделген. Зерттеудің тәжірибелік маңызы – Алматы облысындағы су көздерін ара қашықтан бақылаудың алгоритмін сипаттап жазу. Зерттеудің нәтижесі көрсетті, ара қашықтықтан бақылау үрдісінде жиналған мәлімет тек ақпаратты жинауға ғана емес сонымен қатар мәліметтерді талдауға да қажет.

Түйін сөздер: су көздерін ара қашықтықтан бақылау, ара қашықтан бақылаудың алгоритмі, зерттеу, бейне көрінісі, атмосфералық үрдіс, толық жұтылу коэффиценті, Алматы облысының су көздері.

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ПОТЕНЦИАЛЬНЫЕ МЕТОДЫ АНАЛИЗА ДАННЫХ ЗОНДИРОВАНИЯ ВОДНЫХ ИСТОЧНИКОВ В АЛМАТИНСКОЙ ОБЛАСТИ

Аннотация. В статье описаны потенциальные факторы, которые имеет важность для зондирования водных ресурсов в Алматиснкой области. В данной работе описан алгоритм, который может исправлять новые разработанные методы для анализа данных зондирования.Методология исследования основана на эпистемологии и дедукции. Практическая важность исследования – это описание алгоритма коррекции под атмосферные процессы для зондирования водных источников в Алматинской области.Результаты исследования показывают, что источник сведения, который был собран в качестве данных в процессе зондирования имеет важность не только для сбора информации, но и для анализа данных.Цель исследования – это выяснить, какие факторы должны считаться важными в течении процесса зондирования водных ресурсов.

Ключевые слова: зондирование водных ресурсов, алгоритмы зондирования, излучение, отражение, атмосферные процессы, коэффициент полного рассеяния, водные источники в Алматинской области.