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Annotatsiya: Ushbu maqolada atmosferada gazli aralashmalari va zararli kichik o‘lchamli aerozollarning ko‘chishi va diffuziyasi jarayonining matematik modeli qarab chiqilgan. Ishlab chiqilgan matematik model gaz aralashmalari va zararli moddalarni chiqarish manbalarining ish rejimlarini, shuningdek, ularning o‘rganilayotgan jarayonga ta’sirini hisobga oladi. Boshqa mualliflarning ishlaridan farqli o‘laroq, zarrachalarning cho‘kish tezligi vaqtning har bir qatlamida va har bir fazoviy o‘zgaruvchi uchun alohida ko‘rib chiqilgan. Masalani yechish uchun vaqt va fazoviy o‘zgaruvchilar bo‘yicha yuqori tartibli approksimatsiyaga ega oshkormas ko‘rinishdagi chekli ayirmali sxemadan foydalanib, sonli algoritm ishlab chiqilgan. Ishlab chiqilgan matematik apparat asosida hisoblash tajribalarini o‘tkazishning dasturiy vositasi joriy etildi. Sonli hisoblashlar shuni ko‘rsatdiki, atmosferada gazsimon birikmalar va mayda aerozol zarralarining tarqalishida meteorologik parametrlar asosiy rol o‘ynaydi. O‘rganilayotgan jarayonga o‘simlik qoplami, relyef va ifloslantiruvchi moddaning xususiyatlari sezilarli ta’sir ko‘rsatadi. Tahlillar shuni ko‘rsatadiki, yozda ifloslantiruvchi zarrachalar kamroq hajmda yutiladi, namgarchilik yuqori bo‘lgan mavsumlarda esa ifloslantiruvchi zarrachalarning yutilishi yuqori bo‘ladi.

Kalit so‘zlar: Matenatik model, sonli algoritm, gazli aralashma, approksimatsiya.

Kirish. Jahon ilmiy hamjamiyatida atmosferada zararli moddalarning tarqalish jarayonini kuzatish va bashoratlashning amaliy masalalarini hal etish uchun matematik modellar va hisoblash algoritmlarini ishlab chiqish muammolariga katta e’tibor berilmoqda. Atmosferadagi ifloslantiruvchi moddalar konsentratsiyasining tarqalishini baholash maqsadida, ushbu muammolar dunyoning sanoatlashgan va rivojlanayotgan mamlakatlarida faol o‘rganilmoqda.

Axborot texnologiyalari jadal rivojlanayotgan hozirgi davrda ko‘chish va diffuziya masalalarini yechish matematik modellar, analitik, taqribiy va taqribiy-analitik usullar va ularning dasturiy ta’minoti ko‘rinishida EHMda amalga oshiriladigan samarali matematik apparatni ishlab chiqmasdan tasavvur qilib bo‘lmaydi. Ishlab chiqilgan matematik ta’minot yordamida turli tabiiy va sun’iy sharoitlarda jarayonni tadqiq qilish mumkin.

Suyuqlik va gaz mexanikasi hamda qattiq jismlar mexanikasi, issiqlik va massa ko‘chishining murakkab ko‘p o‘lchovli masalalarini yechish uchun universal usullar qatoriga masalalarning uzluksiz yechim sohasini to‘rli sohaga almashtirishga asoslangan chekli ayirmali usul kiradi.

Shuni ta’kidlash kerakki, masalalarni sonli integrallash uchun ishlatiladigan universal chekli ayirmali sxemalar to‘rlarning har qanday ketma-ketligida va har qanday kirish ma’lumotlari va ularning me’yordan kichik g‘alayonlari uchun usulning yaqinlashishi va turg‘unligi talablarini qanoatlantirishi kerak. Sonli algoritmlarni ishlab chiqishda barcha mavjud usullar: aniq taqribiy, taqribiy-analitik va differensial operatorlarni ayirmali operatorlarga almashtirishga asoslangan sonli usullar, shuningdek, yechimlarni asimptotik baholash, o‘lchov tahlili va eksperimental ma’lumotlar jalb qilinishi kerak.

Adabiyotlar tahlili. [1] maqolada shamol tezliklarining zararli moddalarning atrof-muhitga tarqalishiga ta’siri o‘rganilgan. Shuningdek o‘simlik dunyosining atrof-muhitga yaxshi ma’nodagi ta’siri ham matematik modellar va hisoblash eksperimentlar yordamida ko‘rsatilgan. Jumladan ushbu maqolada daraxtlar orasidagi masofa kamida 20 metr bo‘lish lozimligi ham hisoblash tajriba natijalari asosida ko‘rsatib berilgan.

[2] maqolada transport vositalaridan kelib chiqadigan turbulentlik oqimlarning zararli moddalarning atmosferaga tarqilishiga ta’siri o‘rganilgan. Shuningdek shamolning turli esish yo‘nalishlarida transport vositalarining harakati natijasida vujudga keladigan turbulent kinetik energiyani hisoblaydigan matematik modeli ishlab chiqilgan.

[3] maqolada yo‘l harakati, tabiiy va zaruriy havo konvektiv oqimlari ta’sirida shahar atmosfera muhitini ifodalaydigan matematik model qaralgan. Ushbu matematik model bir yo‘lakli yo‘llardagi transport oqimlarining xususiyatlarini yetarli darajada aniqlik bilan tavsiflangan. Shuningdek ushbu modelning adekvatligi transport oqimlari bo‘yicha hisob tajriba natijalari bilan mos kelishi bilan tekshirilgan.

[4] maqolada atmosferada zararli moddlarning tarqalishining ikki o‘lchovli adveksiya-diffuziyali sonli modeli keltirilgan. Ushbu modelda zararli moddaning o‘zgaruvchan cho‘kish tezligi va girdob-diffuziya jarayonini hisobga olingan. Bu yerda atmosfera dispersiyasini o‘rganish uchun zararli moddaning cho‘kish tezligining ta’siri hisobga olingan. Shuning uchun ushbu tahlilda havo ifloslantiruvchi moddalarning cho‘ktiruvchi ta’sir ostida bo‘lgan hudud manbai bo‘ylab ikki o‘lchovli barqaror holatdagi tarqalishi o‘rganilgan.

[5] maqola atmosferada zararli moddalar tarqalishini bashoratlash uchun yangi yondashuvni taklif etadi. Ushbu yondashuv parametrni baholash texnikasi va mashinali o‘qitish algoritmlarining birlashmasidan foydalanishiga asoslangan. Taklif etilayotgan yondashuvning mohiyati shundaki, kuzatuv nuqtalarida mashinali o‘qitish algoritmlari tomonidan bashoratlangan konsentratsiya qiymatlari konveksiya-diffuziya-reaksiya turidagi differensial tenglama yechimida ifloslantiruvchi moddalar konsentratsiyasini aniqlash uchun foydalanilish mumkinligi ko‘rsatib o‘tilgan. Shuningdek ushbu maqolada kuzatuv nuqtalarida konsentratsiya qiymatlarini bashoratlash uchun uchta qatlamli mashinali o‘qitish algoritmlari tahlil qilingan va bashoratlangan qiymatlar bilan o‘lchash natijalari taqqoslangan.

[6-7] maqolalar mualliflari sanoat hududlari atmosferasining yerga yaqin qatlamida zararli moddalar konsentratsiyasini baholash va atrof-muhitni texnogen ta’sirlardan himoya qilish bo‘yicha qarorlar qabul qilishni qo‘llab-quvvatlash uchun matematik apparat ishlab chiqdilar. Taklif etilgan matematik apparatga asoslanib, sonli hisob-kitoblar amalga

oshirildi. Bu o‘z navbatida aerozol generatorlari va shamol tezligining tashkil etuvchilari jadalligining ortishi bilan moddalarning tarqalish sohasini aniqlash imkonini berdi.

[8] maqolada turli vaqtlarda va mintaqaning turli joylarida zararli moddalarning zichligi qiymatini hisobga olgan holda matematik modelning sonli yechish algoritmi keltirilgan.

[9] maqolada atrof-muhitni salbiy antropogen ta’sirlardan himoya qilish muammosi ko‘rib chiqilgan. Shuningdek, maqolada atmosferaning chegara qatlamini monitoring qilish, bashoratlash va boshqaruv qarorlarini qabul qilish uchun faol aerozol zarralarining tarqalish jarayonini tavsiflovchi matematik model va sonli algoritm ishlab chiqilgan. Sonli integratsiya uchun fazoviy o‘zgaruvchilar va vaqt bo‘yicha yuqori tartibli approksimatsiyani qo‘llagan oshkormas ko‘rinishdagi chekli ayirmali sxema qo‘llanilgan.

[10] maqola mualliflari sanoat hududlari atmosferasidagi havo massalarini o‘rganish, bashoratlash va monitoring qilishni tavsifladilar. Shuningdek fizik xususiyatlarga mos qismlarga ajratish usuli va kompyuterda sonli hisob-kitoblarni tahlil qilish asosida matematik model va samarali sonli algoritm ishlab chiqildi.

[11] maqolada atmosfera chegara qatlamida faol aerozol zarrachalarining chiqarilishi va tarqalishining fazoviy-vaqt o‘zgarishini baholash va bashoratlash uchun kompyuter modelini ishlab chiqishga bag‘ishlangan. Model an’anaviy usulda boshlang‘ich va chegaraviy shartlar bilan birga atmosferada moddalarning ko‘chishi va diffuziyasi bo‘yicha yarim empirik tenglamaga asoslanadi. Hosil bo‘lgan differensial tenglamalarni yechish uchun hisoblash matematikasining chekli ayirmalar, kasr qadamlar va Tomas algoritmi kabi ma’lum usullaridan foydalanilgan.

[12] ishda ochiq veb-xizmatlar va ma’lumotlar omborlari tomonidan taqdim etilgan meteorologik va fazoviy ma’lumotlarni birlashtirish usuli taklif etilgan. Ishlab chiqilgan algoritm sanoat hududlarining ekologik holatini baholash va bashorat qilish masalalarini hal etishdan avval atmosfera chegaraviy qatlamini parametrlash uchun zarur bo‘lgan vaqt va xarajatlarni sezilarli darajada kamaytirishga imkon berdi.

[13]-maqolada GAT texnologiyalari va matematik usullar yordamida vertikal shamolning atmosferaga zararli moddalar tarqalishiga ta’siri o‘rganilgan. Tadqiqot natijalari muayyan balandliklarda hamda yer usti shamol tezligi va g‘adir-budurlik koeffitsiyentining turli qiymatlarida olingan.

[14] tadqiqotda atmosferaning ekologik holatini bashorat qilish, kuzatish va baholash uchun zarrachalarning fizik-kimyoviy xususiyatlarini hisobga oluvchi matematik model ishlab chiqildi. [15] tadqiqotda esa atmosfera chegara qatlamida zararli moddalarning ko‘chishi va tarqalishi jarayonini sonli modellashtirish masalasiga bag‘ishlangan. Muallif sanoat chiqindilarining atmosferada tarqalishini ifodalovchi matematik modelni taklif etgan bo‘lib, unda ikkita muhim omil hisobga olingan: atmosferada kichik o‘lchamli zarrachalarning harakatlanish tezligi hamda ko‘rib chiqilayotgan hududning relyef orografiyasi.

Yuqoridagi nashr etilgan ilmiy ishlarning qisqacha tahlilidan ko‘rinib turibdiki, atmosferada zararli moddalarning tarqalishi va diffuziyasi modellarini ishlab chiqish jarayonida tadqiqotchilar odatda Dekart koordinata tizimlaridan foydalanadilar. Biz ushbu ishda vaqt va fazoviy o‘zgaruvchilarga nisbatan yuqori tartibli approksimatsiya qo‘llagan holda oshkormas ko‘rinishdagi chekli ayirmani qo‘llaymiz.

Masalaning qo‘yilishi. Atmosferada gazli aralashmalar va zararli moddalarning tarqalish jarayonini ifodalovchi matematik modelni quyidagicha ifodalab olamiz:

$$\frac{\partial\theta_{1,m}}{\partial t}+u\frac{\partial\theta_{1,m}}{\partial x}+v\frac{\partial\theta_{1,m}}{\partial y}+w\frac{\partial\theta_{1,m}}{\partial z}+(\sigma+\alpha)\theta_{1,m}=\delta F_{gas}-$$
$$-P_{nucl}-P_{cond}+\mu\frac{\partial^2\theta_{1,m}}{\partial x^2}+\mu\frac{\partial^2\theta_{1,m}}{\partial y^2}+\frac{\partial}{\partial z}\left(\kappa\frac{\partial\theta_{1,m}}{\partial z}\right),$$

(1)

$$\frac{\partial\theta_{2,l}}{\partial t}+u\frac{\partial\theta_{2,l}}{\partial x}+v\frac{\partial\theta_{2,l}}{\partial y}+\bar{w}\frac{\partial\theta_{2,l}}{\partial z}+(\sigma+\alpha)\theta_{2,l}=\delta F_{aer}+$$
$$+P_{nucl}-P_{cond}+\mu\frac{\partial^2\theta_{2,l}}{\partial x^2}+\mu\frac{\partial^2\theta_{2,l}}{\partial y^2}+\frac{\partial}{\partial z}\left(\kappa\frac{\partial\theta_{2,l}}{\partial z}\right),$$
(2)

$$\frac{dw_g}{dt}=\frac{mg-6\pi\eta rw_g-0,5c\rho_z sw_g^2}{m} \quad (3)$$

Bu yerda $\bar{w}=w-w_g$.

(1) xususiy hosilali differensial tenglamalar sistemasi uchun boshlang‘ich va chegaraviy shartlar quyidagicha:

$$\theta_{1,m}\big|_{t=0}=\theta_{1,m}^0; \quad (4)$$

$$-\mu\frac{\partial\theta_{1,m}}{\partial x}\bigg|_{x=0}=\xi\left(\theta_E-\theta_{1,m}\right);$$
$$\mu\frac{\partial\theta_{1,m}}{\partial x}\bigg|_{x=Lx}=\xi\left(\theta_E-\theta_{1,m}\right); \quad (5)$$

$$-\mu\frac{\partial\theta_{1,m}}{\partial y}\bigg|_{y=0}=\xi\left(\theta_E-\theta_{1,m}\right);$$
$$\mu\frac{\partial\theta_{1,m}}{\partial y}\bigg|_{y=L_y}=\xi\left(\theta_E-\theta_{1,m}\right); \quad (6)$$

$$-\kappa\frac{\partial\theta_{1,m}}{\partial z}\bigg|_{z=0}=\left(\beta\theta_{1,m}-f_0\right);$$
$$\kappa\frac{\partial\theta_{1,m}}{\partial z}\bigg|_{z=H_z}=\xi\left(\theta_E-\theta_{1,m}\right). \quad (7)$$

(2) хусусий ҳосилали дифференциал тенгламалар системаси учун бошланғич ва чегаравий шартлар қуйидагича:

$$\theta_{2,l}\big|_{t=0}=\theta_{2,l}^0; \quad w_g\big|_{t=0}=w_g^0; \quad (8)$$

$$-\mu\frac{\partial\theta_{2,l}}{\partial x}\bigg|_{x=0}=\xi\left(\theta_E-\theta_{2,l}\right);$$
$$\mu\frac{\partial\theta_{2,l}}{\partial x}\bigg|_{x=Lx}=\xi\left(\theta_E-\theta_{2,l}\right); \quad (9)$$

$$-\mu\frac{\partial\theta_{2,l}}{\partial y}\bigg|_{y=0}=\xi\left(\theta_E-\theta_{2,l}\right);$$
$$\mu\frac{\partial\theta_{2,l}}{\partial y}\bigg|_{y=L_y}=\xi\left(\theta_E-\theta_{2,l}\right); \quad (10)$$

$$-\kappa\frac{\partial\theta_{2,l}}{\partial z}\bigg|_{z=0}=\left(\beta\theta_{2,l}-f_0\right);$$
$$\kappa\frac{\partial\theta_{2,l}}{\partial z}\bigg|_{z=H_z}=\xi\left(\theta_E-\theta_{2,l}\right). \quad (11)$$

Bu yerda $\theta_{1,m},\ m=\overline{1,N_g}$ – gazli aralashmalarning atmosferadagi konsentratsiyasi; N_g – gazli aralashmalarning soni; $\theta_{2,l},\ l=\overline{1,N_a}$ – zararli moddalarning atmosferadagi konsentratsiyasi; N_a – zararli moddalarning soni; $\theta_{1,m}^0$ – gazli aralashmalarning atmosferadagi boshlang‘ich konsentratsiyasi; $\theta_{2,l}^0$ – zararli moddalarning atmosferadagi boshlang‘ich konsentratsiyasi; θ_E – masala yechimi sohasidan tashqarida zararli moddalarning konsentratsiyasi; $u,\ v,\ w$ – x, y, z yo‘nalishlarida shamol tezligi; w_g – zarrachalarning cho‘kish tezligi; σ – zararli moddalarning atmosferada yutilishi koeffitsiyenti; $\mu,\ \kappa$ – diffuziya va turbulentlik koeffitsiyentlari; F_{gas}, F_{aer} – gazli aralashmalar va zararli moddalar manbaasining quvvati; P_{nucl}, P_{cond} – nukleatsiya va kondensatsiya operatorlari; δ – Dirak funksiyasi; f_0 – zararli moddaning yer sathidan atmosferaga tashlanish jadalligi; $c=0.5$ – o‘lchovsiz kattalik; ρ –

zarrachaning zichligi; r_z – zarrachaning radiusi; s – zarrachaning ko‘ndalang kesim yuzasi; g – erkin tushish tezlanishi; m – zarrachaning massasi; η – zarrachaning solishtirma og‘irligi.

Masalaning sonli yechimi va uning natijalari. (1) xususiy hosilali differensial tenglamani quyidagicha vaqt va fazoviy o‘zgaruvchilarga nisbatan yuqori tartibli approksimatsiyani ishlatgan holda oshkormas ko‘rinishdagi sxemani qo‘llagan holda OX yo‘nalish bo‘yicha quyidagicha chekli ayirmaga kelamiz:

$$\frac{1}{2}\frac{\theta^{n+1/3}_{1,m,i,j,k}-\theta^{n}_{1,m,i,j,k}}{\Delta t/3}+\frac{1}{2}\frac{\theta^{n+1/3}_{1,m,i+1,j,k}-\theta^{n}_{1,m,i+1,j,k}}{\Delta t/3}+$$
$$+\left(\frac{u^{n+1/3}_{i+1,j,k}-\left|u^{n+1/3}_{i,j,k}\right|}{4}\right)\frac{\theta^{n+1/3}_{1,m,i+1,j,k}-\theta^{n+1/3}_{1,m,i,j,k}}{\Delta x}+$$
$$+\left(\frac{u^{n}_{i+1,j,k}-\left|u^{n}_{i,j,k}\right|}{4}\right)\frac{\theta^{n}_{1,m,i+1,j,k}-\theta^{n}_{1,m,i,j,k}}{\Delta x}+$$
$$+\left(\frac{u^{n+1/3}_{i,j,k}+\left|u^{n+1/3}_{i-1,j,k}\right|}{4}\right)\frac{\theta^{n+1/3}_{1,m,i,j,k}-\theta^{n+1/3}_{1,m,i-1,j,k}}{\Delta x}+$$
$$+\left(\frac{u^{n}_{i,j,k}+\left|u^{n}_{i-1,j,k}\right|}{4}\right)\frac{\theta^{n}_{1,m,i,j,k}-\theta^{n}_{1,m,i-1,j,k}}{\Delta x}+$$
$$+\left(\frac{v^{n}_{i,j+1,k}-\left|v^{n}_{i,j,k}\right|}{2}\right)\frac{\theta^{n}_{1,m,i,j+1,k}-\theta^{n}_{1,m,i,j,k}}{\Delta y}+$$
$$+\left(\frac{v^{n}_{i,j,k}+\left|v^{n}_{i,j-1,k}\right|}{2}\right)\frac{\theta^{n}_{1,m,i,j,k}-\theta^{n}_{1,m,i,j-1,k}}{\Delta y}+$$
$$+\left(\frac{w^{n}_{i,j,k+1}-\left|w^{n}_{i,j,k}\right|}{2}\right)\frac{\theta^{n}_{1,m,i,j,k+1}-\theta^{n}_{1,m,i,j,k}}{\Delta z}+$$
$$+\left(\frac{w^{n}_{i,j,k}+\left|w^{n}_{i,j,k-1}\right|}{2}\right)\frac{\theta^{n}_{1,m,i,j,k}-\theta^{n}_{1,m,i,j,k-1}}{\Delta z}+$$
$$+(\sigma+\alpha)\theta^{n+1/3}_{1,m,i,j,k}=$$
$$=\frac{\mu}{\Delta x^2}\left(\theta^{n+1/3}_{1,m,i+1,j,k}-2\theta^{n+1/3}_{1,m,i,j,k}+\theta^{n+1/3}_{1,m,i-1,j,k}\right)+$$
$$+\frac{\mu}{\Delta y^2}\left(\theta^{n}_{1,m,i,j+1,k}-2\theta^{n}_{1,m,i,j,k}+\theta^{n}_{1,m,i,j-1,k}\right)+$$
$$+\frac{1}{\Delta z^2}\left(\kappa_{k+0,5}\theta^{n}_{1,m,i,j,k+1}-\left(\kappa_{k+0,5}+\kappa_{k-0,5}\right)\theta^{n}_{1,m,i,j,k}+\kappa_{k-0,5}\theta^{n}_{1,m,i,j,k-1}\right)+$$
$$+\frac{1}{3}\left(\delta_{i,j,k}F_{gas}-P_{nucl}-P_{cond}\right).$$

Qavslarni ochib chiqib, o‘xshash hadlarni ixchamlaymiz va quyidagiga kelamiz:

$$\left(\frac{\mu}{\Delta x^2}+\frac{u^{n+1/3}_{i-1,j,k}+\left|u^{n+1/3}_{i-1,j,k}\right|}{4\Delta x}\right)\theta^{n+1/3}_{1,m,i-1,j,k}-$$
$$-\left(\frac{2\mu}{\Delta x^2}+\frac{\left|u^{n+1/3}_{i,j,k}\right|}{2\Delta x}+\frac{3}{2\Delta t}+\sigma+\alpha\right)\theta^{n+1/3}_{1,m,i,j,k}+$$
$$+\left(\frac{\mu}{\Delta x^2}-\frac{u^{n+1/3}_{i+1,j,k}-\left|u^{n+1/3}_{i+1,j,k}\right|}{4\Delta x}-\frac{3}{2\Delta t}\right)\theta^{n+1/3}_{1,m,i+1,j,k}=$$
$$=-\left(\left(\frac{u^{n}_{i-1,j,k}+\left|u^{n}_{i-1,j,k}\right|}{4\Delta x}\right)\theta^{n}_{1,m,i-1,j,k}+\right.$$

$$+\left(\frac{3}{2\Delta t}-\frac{u^n_{i+1,j,k}-\left|u^n_{i+1,j,k}\right|}{4\Delta x}\right)\theta^n_{1,m,i+1,j,k}+$$

$$+\left(\frac{3}{2\Delta t}-\frac{2\mu}{\Delta y^2}-\frac{\kappa_{k+0,5}+\kappa_{k-0,5}}{\Delta z^2}-\frac{\left|u^n_{i,j,k}\right|}{2\Delta x}-\frac{\left|v^n_{i,j,k}\right|}{\Delta y}-\frac{\left|w^n_{i,j,k}\right|}{\Delta z}\right)\theta^n_{1,m,i,j,k}+$$

$$+\left(\frac{\mu}{\Delta y^2}+\frac{v^n_{i,j-1,k}+\left|v^n_{i,j-1,k}\right|}{2\Delta y}\right)\theta^n_{1,m,i,j-1,k}+$$

$$+\left(\frac{\mu}{\Delta y^2}-\frac{v^n_{i,j+1,k}-\left|v^n_{i,j+1,k}\right|}{2\Delta y}\right)\theta^n_{1,m,i,j+1,k}+$$

$$+\left(\frac{\kappa_{k-0,5}}{\Delta z^2}+\frac{w^n_{i,j,k-1}+\left|w^n_{i,j,k-1}\right|}{2\Delta z}\right)\theta^n_{1,m,i,j,k-1}+$$

$$+\left(\frac{\kappa_{k+0,5}}{\Delta z^2}-\frac{w^n_{i,j,k+1}-\left|w^n_{i,j,k+1}\right|}{2\Delta z}\right)\theta^n_{1,m,i,j,k+1}+\frac{1}{3}\left(\delta_{i,j,k}F_{gas}-P_{nucl}-P_{cond}\right)$$

Quyidagi belgilashlarni kiritamiz:

$$a_{1,m,i,j,k}=\frac{\mu}{\Delta x^2}+\frac{u^{n+1/3}_{i-1,j,k}+\left|u^{n+1/3}_{i-1,j,k}\right|}{4\Delta x};$$

$$b_{1,m,i,j,k}=\frac{2\mu}{\Delta x^2}+\frac{\left|u^{n+1/3}_{i,j,k}\right|}{2\Delta x}+\frac{3}{2\Delta t}+\sigma+\alpha;$$

$$c_{1,m,i,j,k}=\frac{\mu}{\Delta x^2}-\frac{u^{n+1/3}_{i-1,j,k}-\left|u^{n+1/3}_{i-1,j,k}\right|}{4\Delta x}-\frac{3}{2\Delta t};$$

$$d_{1,m,i,j,k}=\left(\frac{3}{2\Delta t}-\frac{2\mu}{\Delta y^2}-\frac{\kappa_{k+0,5}+\kappa_{k-0,5}}{\Delta z^2}-\frac{\left|u^n_{i,j,k}\right|}{2\Delta x}-\frac{\left|v^n_{i,j,k}\right|}{\Delta y}-\frac{\left|w^n_{i,j,k}\right|}{\Delta z}\right)\theta^n_{i,j,k}+$$

$$+\left(\frac{u^n_{i-1,j,k}+\left|u^n_{i-1,j,k}\right|}{4\Delta x}\right)\theta^n_{i-1,j,k}+\left(\frac{3}{2\Delta t}-\frac{u^n_{i+1,j,k}-\left|u^n_{i+1,j,k}\right|}{4\Delta x}\right)\theta^n_{i+1,j,k}+$$

$$+\left(\frac{\mu}{\Delta y^2}+\frac{v^n_{i,j-1,k}+\left|v^n_{i,j-1,k}\right|}{2\Delta y}\right)\theta^n_{i,j-1,k}+\left(\frac{\mu}{\Delta y^2}-\frac{v^n_{i,j+1,k}-\left|v^n_{i,j+1,k}\right|}{2\Delta y}\right)\theta^n_{i,j+1,k}+$$

$$+\left(\frac{\kappa_{k-0,5}}{\Delta z^2}+\frac{w^n_{i,j,k-1}+\left|w^n_{i,j,k-1}\right|}{2\Delta z}\right)\theta^n_{i,j,k-1}+\left(\frac{\kappa_{k+0,5}}{\Delta z^2}-\frac{w^n_{i,j,k+1}-\left|w^n_{i,j,k+1}\right|}{2\Delta z}\right)\theta^n_{i,j,k+1}+$$

$$+\frac{1}{3}\left(\delta_{i,j,k}F_{gas}-P_{nucl}-P_{cond}\right).$$

Natijada quyidagi chiziqli algebraik tenglamalar sistemasiga kelamiz:

$$a_{1,m,i,j,k}\theta^{n+1/3}_{1,m,i-1,j,k}-b_{1,m,i,j,k}\theta^{n+1/3}_{1,m,i,j,k}+c_{1,m,i,j,k}\theta^{n+1/3}_{1,m,i+1,j,k}=-d_{1,m,i,j,k},$$

(6)

Shuningdek, (3) chegaraviy shartni x=0 uchun quyidagicha ikkinchi tartibdagi aniqlikda aproksimatsiyalaymiz:

$$-\mu\frac{-3\theta^{n+1/3}_{1,m,0,j,k}+4\theta^{n+1/3}_{1,m,1,j,k}-\theta^{n+1/3}_{1,m,2,j,k}}{2\Delta x}=\xi\theta^{n+1/3}_{1,m,0,j,k}-\xi\theta_E.$$

Ushbu ifodani soddalashtiramiz va quyidagiga kelamiz:

$$3\mu\theta^{n+1/3}_{1,m,0,j,k}-4\mu\theta^{n+1/3}_{1,m,1,j,k}+\mu\theta^{n+1/3}_{1,m,2,j,k}=2\Delta x\xi\theta^{n+1/3}_{1,m,0,j,k}-2\Delta x\xi\theta_E;$$

(7)

Quyidagi uch diagonalli tenglamalar sistemasidan $\theta^{n+1/3}_{1,m,2,j,k}$ ni topamiz:

$$a_{1,m,1,j,k}\theta^{n+1/3}_{1,m,0,j,k}-b_{1,m,1,j,k}\theta^{n+1/3}_{1,m,1,j,k}+c_{1,m,1,j,k}\theta^{n+1/3}_{1,m,2,j,k}=-d_{1,m,1,j,k},$$

$$\theta^{n+1/3}_{1,m,2,j,k}=-\frac{a_{1,m,1,j,k}}{c_{1,m,1,j,k}}\theta^{n+1/3}_{1,m,0,j,k}+\frac{b_{1,m,1,j,k}}{c_{1,m,1,j,k}}\theta^{n+1/3}_{1,m,1,j,k}-\frac{d_{1,m,1,j,k}}{c_{1,m,1,j,k}};$$

(8)

(8) ni (7) dagi $\theta^{n+1/3}_{1,m,2,j,k}$ ning joyiga olib borib qo’yamiz va natijada $\theta^{n+1/3}_{1,m,0,j,k}$ ni quyidagicha topamiz:

$$\theta^{n+1/3}_{1,m,0,j,k}=\frac{\left(4c_{1,m,1,j,k}-b_{1,m,1,j,k}\right)\mu}{\left(3c_{1,m,1,j,k}-a_{1,m,1,j,k}\right)\mu-2\Delta x\xi}\theta^{n+1/3}_{1,m,1,j,k}+\frac{d_{1,m,1,j,k}\mu-2\Delta x\xi c_{1,m,1,j,k}\theta_E}{\left(3c_{1,m,1,j,k}-a_{1,m,1,j,k}\right)\mu-2\Delta x\xi};$$

Progonka usulidan foydalanib $\alpha_{1,m,0,j,k}$ va $\beta_{1,m,0,j,k}$ ni quyidagicha topamiz:

$$\alpha_{1,m,0,j,k}=\frac{\left(4c_{1,m,1,j,k}-b_{1,m,1,j,k}\right)\mu}{\left(3c_{1,m,1,j,k}-a_{1,m,1,j,k}\right)\mu-2\Delta x\xi};$$

$$\beta_{1,m,0,j,k}=\frac{d_{1,m,1,j,k}\mu-2\Delta x\xi c_{1,m,1,j,k}\theta_E}{\left(3c_{1,m,1,j,k}-a_{1,m,1,j,k}\right)\mu-2\Delta x\xi}.$$

Shuningdek (3) – chegaraviy shartni $x = L_x$ uchun quyidagicha ikkinchi tartibdagi aniqlikda aproksimatsiyalaymiz:

$$\mu\frac{\theta^{n+1/3}_{1,m,N-2,j,k}-4\theta^{n+1/3}_{1,m,N-1,j,k}+3\theta^{n+1/3}_{1,m,N,j,k}}{2\Delta x}=\xi\theta^{n+1/3}_{1,m,N,j,k}-\xi\theta_E$$

$$\mu\theta^{n+1/3}_{1,m,N-2,j,k}-4\mu\theta^{n+1/3}_{1,m,N-1,j,k}+3\mu\theta^{n+1/3}_{1,m,N,j,k}=2\Delta x\xi\theta^{n+1/3}_{1,m,N,j,k}-2\Delta x\xi\theta_E;$$

(9)

Progonka usulini quyidagicha ketma-ket *N*, *N-1* va *N-2* lar uchun qo’llaymiz va $\theta^{n+1/3}_{1,m,N-1,j,k}$ va $\theta^{n+1/3}_{1,m,N-2,j,k}$ larni topamiz:

$$\theta^{n+1/3}_{1,m,N-1,j,k}=\alpha_{1,m,N-1,j,k}\theta^{n+1/3}_{1,m,N,j,k}+\beta_{1,m,N-1,j,k};$$

(10)

$$\theta_{1,m,N-2,j,k}^{n+1/3}=\alpha_{1,m,N-2,j,k}\theta_{1,m,N-1,j,k}^{n+1/3}+\beta_{1,m,N-2,j,k}=$$
$$=\alpha_{1,m,N-2,j,k}\left(\alpha_{1,m,N-1,j,k}\theta_{1,m,N,j,k}^{n+1/3}+\beta_{1,m,N-1,j,k}\right)+\beta_{1,m,N-2,j,k}=$$
$$=\alpha_{1,m,N-2,j,k}\alpha_{1,m,N-1,j,k}\theta_{1,m,N,j,k}^{n+1/3}+\alpha_{1,m,N-2,j,k}\beta_{1,m,N-1,j,k}+\beta_{1,m,N-2,j,k};$$

(11)

(10) va (11)lardagi $\theta_{1,m,N-1,j,k}^{n+1/3}$ va $\theta_{1,m,N-2,j,k}^{n+1/3}$ larni (9) dagi $\theta_{1,m,N-1,j,k}^{n+1/3}$ va $\theta_{1,m,N-2,j,k}^{n+1/3}$ larning o’rniga qo’yib, $\theta_{1,m,N,j,k}^{n+1/3}$ ni topamiz:

$$\theta_{1,m,N,j,k}^{n+1/3}=\frac{-2\Delta x\xi\theta_E-\left(\beta_{1,m,N-2,j,k}+\alpha_{1,m,N-2,j,k}\beta_{1,m,N-1,j,k}-4\beta_{1,m,N-1,j,k}\right)\mu}{-2\Delta x\xi+\left(\alpha_{1,m,N-2,j,k}\alpha_{1,m,N-1,j,k}-4\alpha_{1,m,N-1,j,k}+3\right)\mu}.$$

$$\theta_{1,m,N-1,j,k}^{n+1/3},\theta_{1,m,N-2,j,k}^{n+1/3},\ldots,\theta_{1,m,1,j,k}^{n+1/3}$$

konsentratsiya qiymatlarining ketma-ketligi teskari progonka usuli yordamida topiladi.

$$\theta_{1,m,i,j,k}^{n+1/3}=\alpha_{1,m,i,j,k}\theta_{1,m,i+1,j,k}^{n+1/3}+\beta_{1,m,i,j,k};\ i=N-1,0,\ \ j=1,M-1,\ k=1,L-1.$$

Yuqorida bajarilgan amallar ketma-ketligini OY va OZ yo‘nalishlar uchun ham qo‘llaymiz. Natijada quyidagiga kelamiz:

OY yo‘nalish uchun:

$$\bar{a}_{1,m,i,j,k}\theta_{1,m,i,j-1,k}^{n+2/3}-\bar{b}_{1,m,i,j,k}\theta_{1,m,i,j,k}^{n+2/3}+\bar{c}_{1,m,i,j,k}\theta_{1,m,i,j+1,k}^{n+2/3}=-\bar{d}_{1,m,i,j,k},$$

$$\bar{a}_{1,m,i,j,k}=\frac{\mu}{\Delta y^2}+\frac{v_{i,j-1,k}^{n+2/3}+\left|v_{i,j-1,k}^{n+2/3}\right|}{4\Delta y};$$

$$\bar{b}_{1,m,i,j,k}=\frac{2\mu}{\Delta y^2}+\frac{\left|v_{i,j,k}^{n+2/3}\right|}{2\Delta y}+\frac{3}{2\Delta t}+\sigma+\alpha;$$

$$\bar{c}_{1,m,i,j,k}=\frac{\mu}{\Delta y^2}-\frac{v_{i,j+1,k}^{n+2/3}-\left|v_{i,j+1,k}^{n+2/3}\right|}{4\Delta y}-\frac{3}{2\Delta t};$$

$$\bar{d}_{1,m,i,j,k}=\left(\frac{3}{2\Delta t}-\frac{2\mu}{\Delta x^2}-\frac{\kappa_{k+0,5}+\kappa_{k-0,5}}{\Delta z^2}-\frac{\left|u_{i,j,k}^{n+1/3}\right|}{\Delta x}-\frac{\left|v_{i,j,k}^{n+1/3}\right|}{2\Delta y}-\frac{\left|w_{i,j,k}^{n+1/3}\right|}{\Delta z}\right)\theta_{1,m,i,j,k}^{n+1/3}+$$
$$+\left(\frac{\mu}{\Delta x^2}+\frac{u_{i-1,j,k}^{n+1/3}+\left|u_{i-1,j,k}^{n+1/3}\right|}{2\Delta x}\right)\theta_{1,m,i-1,j,k}^{n+1/3}+\left(\frac{\mu}{\Delta x^2}-\frac{u_{i+1,j,k}^{n+1/3}-\left|u_{i+1,j,k}^{n+1/3}\right|}{2\Delta x}\right)\theta_{1,m,i+1,j,k}^{n+1/3}+$$
$$+\left(\frac{v_{i,j-1,k}^{n+1/3}+\left|v_{i,j-1,k}^{n+1/3}\right|}{4\Delta y}\right)\theta_{1,m,i,j-1,k}^{n+1/3}+\left(\frac{3}{2\Delta t}-\frac{v_{i,j+1,k}^{n+1/3}-\left|v_{i,j+1,k}^{n+1/3}\right|}{4\Delta y}\right)\theta_{1,m,i,j+1,k}^{n+1/3}+$$
$$+\left(\frac{\kappa_{k-0,5}}{\Delta z^2}+\frac{w_{i,j,k-1}^{n+1/3}+\left|w_{i,j,k-1}^{n+1/3}\right|}{2\Delta z}\right)\theta_{i,j,k-1}^{n+1/3}+\left(\frac{\kappa_{k+0,5}}{\Delta z^2}-\frac{w_{i,j,k+1}^{n+1/3}-\left|w_{i,j,k+1}^{n+1/3}\right|}{2\Delta z}\right)\theta_{1,m,i,j,k+1}^{n+1/3}+$$
$$+\frac{1}{3}\left(\delta_{i,j,k}F_{gas}-P_{nucl}-P_{cond}\right).$$

$$\bar{\alpha}_{1,m,i,0,k}=\frac{4\mu\bar{c}_{1,m,i,1,k}-\bar{b}_{1,m,i,1,k}\mu}{3\mu\bar{c}_{1,m,i,1,k}-\bar{a}_{1,m,i,1,k}\mu+2\Delta y\xi};$$

$$\bar{\beta}_{1,m,i,0,k}=\frac{\bar{d}_{1,m,i,1,k}\mu+2\Delta y\bar{c}_{1,m,i,1,k}\xi\theta_E}{3\mu\bar{c}_{1,m,i,1,k}-\bar{a}_{1,m,i,1,k}\mu+2\Delta y\xi}.$$

$$\theta_{1,m,i,M,k}^{n+2/3}=\frac{2\Delta y\xi\theta_E-\left(\bar{\beta}_{1,m,i,M-2,k}+\bar{\alpha}_{1,m,i,M-2,k}\bar{\beta}_{1,m,i,M-1,k}-4\bar{\beta}_{1,m,i,M-1,k}\right)\mu}{2\Delta y\xi+\left(\bar{\alpha}_{1,m,i,M-2,k}\bar{\alpha}_{1,m,i,M-1,k}-4\bar{\alpha}_{1,m,i,M-1,k}+3\right)\mu}.$$

OZ yo‘nalish uchun:

$$\bar{\bar{a}}_{1,m,i,j,k}\theta_{1,m,i,j,k-1}^{n+1}-\bar{\bar{b}}_{1,m,i,j,k}\theta_{1,m,i,j,k}^{n+1}+\bar{\bar{c}}_{1,m,i,j,k}\theta_{1,m,i,j,k+1}^{n+1}=-\bar{\bar{d}}_{1,m,i,j,k},$$

$$\bar{\bar{a}}_{1,m,i,j,k}=\frac{\kappa_{k-0,5}}{\Delta z^2}+\frac{w_{i,j,k-1}^{n+1}+\left|w_{i,j,k-1}^{n+1}\right|}{4\Delta z};$$

$$\bar{\bar{b}}_{1,m,i,j,k}=\frac{\kappa_{k-0,5}+\kappa_{k+0,5}}{\Delta z^2}+\frac{\left|w_{i,j,k}^{n+1}\right|}{2\Delta z}+\frac{3}{2\Delta t}+\sigma+\alpha;$$

$$\bar{\bar{c}}_{1,m,i,j,k}=\frac{\kappa_{k+0,5}}{\Delta z^2}-\frac{w_{i,j,k+1}^{n+1}-\left|w_{i,j,k+1}^{n+1}\right|}{4\Delta z}-\frac{3}{2\Delta t};$$

$$\bar{\bar{d}}_{1,m,i,j,k}=\left(\frac{3}{2\Delta t}-\frac{2\mu}{\Delta x^2}-\frac{2\mu}{\Delta y^2}-\frac{\left|u_{i,j,k}^{n+2/3}\right|}{\Delta x}-\frac{\left|v_{i,j,k}^{n+2/3}\right|}{\Delta y}-\frac{\left|w_{i,j,k}^{n+2/3}\right|}{2\Delta z}\right)\theta_{1,m,i,j,k}^{n+2/3}+$$
$$+\left(\frac{\mu}{\Delta x^2}+\frac{u_{i-1,j,k}^{n+2/3}+\left|u_{i-1,j,k}^{n+2/3}\right|}{2\Delta x}\right)\theta_{1,m,i-1,j,k}^{n+2/3}+\left(\frac{\mu}{\Delta x^2}-\frac{u_{i+1,j,k}^{n+2/3}-\left|u_{i+1,j,k}^{n+2/3}\right|}{2\Delta x}\right)\theta_{1,m,i+1,j,k}^{n+2/3}+$$
$$+\left(\frac{\mu}{\Delta y^2}+\frac{v_{i,j-1,k}^{n+2/3}+\left|v_{i,j-1,k}^{n+2/3}\right|}{2\Delta y}\right)\theta_{1,m,i,j-1,k}^{n+2/3}+\left(\frac{\mu}{\Delta y^2}-\frac{v_{i,j+1,k}^{n+2/3}-\left|v_{i,j+1,k}^{n+2/3}\right|}{2\Delta y}\right)\theta_{1,m,i,j+1,k}^{n+2/3}+$$
$$+\left(\frac{w_{i,j,k-1}^{n+2/3}+\left|w_{i,j,k-1}^{n+2/3}\right|}{4\Delta z}\right)\theta_{i,j,k-1}^{n+2/3}+\left(\frac{3}{2\Delta t}-\frac{w_{i,j,k+1}^{n+2/3}-\left|w_{i,j,k+1}^{n+2/3}\right|}{4\Delta z}\right)\theta_{1,m,i,j,k+1}^{n+2/3}+$$
$$+\frac{1}{3}\left(\delta_{i,j,k}F_{gas}-P_{nucl}-P_{cond}\right).$$

$$\bar{\bar{\alpha}}_{1,m,i,j,0}=\frac{4\kappa_1\bar{\bar{c}}_{1,m,i,j,1}-\bar{\bar{b}}_{1,m,i,j,1}\kappa_1}{3\kappa_1\bar{\bar{c}}_{1,m,i,j,1}-\bar{\bar{a}}_{1,m,i,j,1}\kappa_1-2\Delta z\beta\bar{\bar{c}}_{1,m,i,j,1}};$$

$$\bar{\bar{\beta}}_{1,m,i,j,0}=\frac{\bar{\bar{d}}_{1,m,i,j,1}\kappa_1+2\Delta z\bar{\bar{c}}_{1,m,i,j,1}f_0}{3\kappa_1\bar{\bar{c}}_{1,m,i,j,1}-\bar{\bar{a}}_{1,m,i,j,1}\kappa_1-2\Delta z\beta\bar{\bar{c}}_{1,m,i,j,1}}.$$

$$\theta_{1,m,i,j,L}^{n+1}=\frac{2\Delta z\xi\theta_E-\left(\bar{\bar{\beta}}_{1,m,i,j,L-2}+\bar{\bar{\alpha}}_{1,m,i,j,L-2}\bar{\bar{\beta}}_{1,m,i,j,L-1}-4\bar{\bar{\beta}}_{1,m,i,j,L-1}\right)\kappa_L}{2\Delta z\xi+\left(\bar{\bar{\alpha}}_{1,m,i,j,L-2}\bar{\bar{\alpha}}_{1,m,i,j,L-1}-4\bar{\bar{\alpha}}_{1,m,i,j,L-1}+3\right)\kappa_L}.$$

Yuqoridagi amallar ketma-ketligini (2) xususiy hosilali differensial tenglama uchun ham qo‘llaymiz va quyidagiga kelamiz:

OX yo‘nalish uchun:

$$a_{1,m,i,j,k}\theta_{1,m,i-1,j,k}^{n+1/3}-b_{1,m,i,j,k}\theta_{1,m,i,j,k}^{n+1/3}+c_{1,m,i,j,k}\theta_{1,m,i+1,j,k}^{n+1/3}=-d_{1,m,i,j,k},$$

$$a_{1,m,i,j,k}=\frac{\mu}{\Delta x^2}+\frac{u_{i-1,j,k}^{n+1/3}+\left|u_{i-1,j,k}^{n+1/3}\right|}{4\Delta x};$$

$$b_{1,m,i,j,k}=\frac{2\mu}{\Delta x^2}+\frac{\left|u_{i,j,k}^{n+1/3}\right|}{2\Delta x}+\frac{3}{2\Delta t}+\sigma+\alpha;$$

$$c_{1,m,i,j,k}=\frac{\mu}{\Delta x^2}-\frac{u_{i-1,j,k}^{n+1/3}-\left|u_{i-1,j,k}^{n+1/3}\right|}{4\Delta x}-\frac{3}{2\Delta t};$$

$$d_{1,m,i,j,k}=\left(\frac{3}{2\Delta t}-\frac{2\mu}{\Delta y^2}-\frac{\kappa_{k+0,5}+\kappa_{k-0,5}}{\Delta z^2}-\frac{\left|u_{i,j,k}^{n}\right|}{2\Delta x}-\frac{\left|v_{i,j,k}^{n}\right|}{\Delta y}-\frac{\left|w_{i,j,k}^{n}\right|}{\Delta z}\right)\theta_{i,j,k}^{n}+$$
$$+\left(\frac{u_{i-1,j,k}^{n}+\left|u_{i-1,j,k}^{n}\right|}{4\Delta x}\right)\theta_{i-1,j,k}^{n}+\left(\frac{3}{2\Delta t}-\frac{u_{i+1,j,k}^{n}-\left|u_{i+1,j,k}^{n}\right|}{4\Delta x}\right)\theta_{i+1,j,k}^{n}+$$
$$+\left(\frac{\mu}{\Delta y^2}+\frac{v_{i,j-1,k}^{n}+\left|v_{i,j-1,k}^{n}\right|}{2\Delta y}\right)\theta_{i,j-1,k}^{n}+\left(\frac{\mu}{\Delta y^2}-\frac{v_{i,j+1,k}^{n}-\left|v_{i,j+1,k}^{n}\right|}{2\Delta y}\right)\theta_{i,j+1,k}^{n}+$$
$$+\left(\frac{\kappa_{k-0,5}}{\Delta z^2}+\frac{w_{i,j,k-1}^{n}+\left|w_{i,j,k-1}^{n}\right|}{2\Delta z}\right)\theta_{i,j,k-1}^{n}+\left(\frac{\kappa_{k+0,5}}{\Delta z^2}-\frac{w_{i,j,k+1}^{n}-\left|w_{i,j,k+1}^{n}\right|}{2\Delta z}\right)\theta_{i,j,k+1}^{n}+$$
$$+\frac{1}{3}\left(\delta_{i,j,k}F_{gas}-P_{nucl}-P_{cond}\right).$$

$$\alpha_{1,m,0,j,k}=\frac{\left(4c_{1,m,1,j,k}-b_{1,m,1,j,k}\right)\mu}{\left(3c_{1,m,1,j,k}-a_{1,m,1,j,k}\right)\mu-2\Delta x\xi};$$

$$\beta_{1,m,0,j,k}=\frac{d_{1,m,1,j,k}\mu-2\Delta x\xi c_{1,m,1,j,k}\theta_E}{\left(3c_{1,m,1,j,k}-a_{1,m,1,j,k}\right)\mu-2\Delta x\xi}.$$

$$\theta_{1,m,N,j,k}^{n+1/3}=\frac{-2\Delta x\xi\theta_E-\left(\beta_{1,m,N-2,j,k}+\alpha_{1,m,N-2,j,k}\beta_{1,m,N-1,j,k}-4\beta_{1,m,N-1,j,k}\right)\mu}{-2\Delta x\xi+\left(\alpha_{1,m,N-2,j,k}\alpha_{1,m,N-1,j,k}-4\alpha_{1,m,N-1,j,k}+3\right)\mu}.$$

OY yo‘nalish uchun:

$$\bar{a}_{1,m,i,j,k}\theta_{1,m,i,j-1,k}^{n+2/3}-\bar{b}_{1,m,i,j,k}\theta_{1,m,i,j,k}^{n+2/3}+\bar{c}_{1,m,i,j,k}\theta_{1,m,i,j+1,k}^{n+2/3}=-\bar{d}_{1,m,i,j,k},$$

$$\bar{a}_{1,m,i,j,k}=\frac{\mu}{\Delta y^2}+\frac{v_{i,j-1,k}^{n+2/3}+\left|v_{i,j-1,k}^{n+2/3}\right|}{4\Delta y};$$

$$\bar{b}_{1,m,i,j,k}=\frac{2\mu}{\Delta y^2}+\frac{\left|v_{i,j,k}^{n+2/3}\right|}{2\Delta y}+\frac{3}{2\Delta t}+\sigma+\alpha;$$

$$\bar{c}_{1,m,i,j,k}=\frac{\mu}{\Delta y^2}-\frac{v_{i,j+1,k}^{n+2/3}-\left|v_{i,j+1,k}^{n+2/3}\right|}{4\Delta y}-\frac{3}{2\Delta t};$$

$$\bar{d}_{1,m,i,j,k}=\left(\frac{3}{2\Delta t}-\frac{2\mu}{\Delta x^2}-\frac{\kappa_{k+0,5}+\kappa_{k-0,5}}{\Delta z^2}-\frac{\left|u_{i,j,k}^{n+1/3}\right|}{\Delta x}-\frac{\left|v_{i,j,k}^{n+1/3}\right|}{2\Delta y}-\frac{\left|w_{i,j,k}^{n+1/3}\right|}{\Delta z}\right)\theta_{1,m,i,j,k}^{n+1/3}+$$
$$+\left(\frac{\mu}{\Delta x^2}+\frac{u_{i-1,j,k}^{n+1/3}+\left|u_{i-1,j,k}^{n+1/3}\right|}{2\Delta x}\right)\theta_{1,m,i-1,j,k}^{n+1/3}+\left(\frac{\mu}{\Delta x^2}-\frac{u_{i+1,j,k}^{n+1/3}-\left|u_{i+1,j,k}^{n+1/3}\right|}{2\Delta x}\right)\theta_{1,m,i+1,j,k}^{n+1/3}+$$
$$+\left(\frac{v_{i,j-1,k}^{n+1/3}+\left|v_{i,j-1,k}^{n+1/3}\right|}{4\Delta y}\right)\theta_{1,m,i,j-1,k}^{n+1/3}+\left(\frac{3}{2\Delta t}-\frac{v_{i,j+1,k}^{n+1/3}-\left|v_{i,j+1,k}^{n+1/3}\right|}{4\Delta y}\right)\theta_{1,m,i,j+1,k}^{n+1/3}+$$
$$+\left(\frac{\kappa_{k-0,5}}{\Delta z^2}+\frac{w_{i,j,k-1}^{n+1/3}+\left|w_{i,j,k-1}^{n+1/3}\right|}{2\Delta z}\right)\theta_{i,j,k-1}^{n+1/3}+\left(\frac{\kappa_{k+0,5}}{\Delta z^2}-\frac{w_{i,j,k+1}^{n+1/3}-\left|w_{i,j,k+1}^{n+1/3}\right|}{2\Delta z}\right)\theta_{1,m,i,j,k+1}^{n+1/3}+$$
$$+\frac{1}{3}\left(\delta_{i,j,k}F_{gas}-P_{nucl}-P_{cond}\right).$$

$$\bar{\alpha}_{1,m,i,0,k}=\frac{4\mu\bar{c}_{1,m,i,1,k}-\bar{b}_{1,m,i,1,k}\mu}{3\mu\bar{c}_{1,m,i,1,k}-\bar{a}_{1,m,i,1,k}\mu+2\Delta y\xi};$$

$$\bar{\beta}_{1,m,i,0,k}=\frac{\bar{d}_{1,m,i,1,k}\mu+2\Delta y\bar{c}_{1,m,i,1,k}\xi\theta_E}{3\mu\bar{c}_{1,m,i,1,k}-\bar{a}_{1,m,i,1,k}\mu+2\Delta y\xi}.$$

$$\theta_{1,m,i,M,k}^{n+2/3}=\frac{2\Delta y\xi\theta_E-\left(\bar{\beta}_{1,m,i,M-2,k}+\bar{\alpha}_{1,m,i,M-2,k}\bar{\beta}_{1,m,i,M-1,k}-4\bar{\beta}_{1,m,i,M-1,k}\right)\mu}{2\Delta y\xi+\left(\bar{\alpha}_{1,m,i,M-2,k}\bar{\alpha}_{1,m,i,M-1,k}-4\bar{\alpha}_{1,m,i,M-1,k}+3\right)\mu}.$$

OZ yo‘nalish uchun:

$$\bar{\bar{a}}_{1,m,i,j,k}\theta_{1,m,i,j,k-1}^{n+1}-\bar{\bar{b}}_{1,m,i,j,k}\theta_{1,m,i,j,k}^{n+1}+\bar{\bar{c}}_{1,m,i,j,k}\theta_{1,m,i,j,k+1}^{n+1}=-\bar{\bar{d}}_{1,m,i,j,k},$$

$$\bar{\bar{a}}_{1,m,i,j,k}=\frac{\kappa_{k-0,5}}{\Delta z^2}+\frac{w_{i,j,k-1}^{n+1}+\left|w_{i,j,k-1}^{n+1}\right|}{4\Delta z};$$

$$\bar{\bar{b}}_{1,m,i,j,k}=\frac{\kappa_{k-0,5}+\kappa_{k+0,5}}{\Delta z^2}+\frac{\left|w_{i,j,k}^{n+1}\right|}{2\Delta z}+\frac{3}{2\Delta t}+\sigma+\alpha;$$

$$\bar{\bar{c}}_{1,m,i,j,k}=\frac{\kappa_{k+0,5}}{\Delta z^2}-\frac{w_{i,j,k+1}^{n+1}-\left|w_{i,j,k+1}^{n+1}\right|}{4\Delta z}-\frac{3}{2\Delta t};$$

$$\bar{\bar{d}}_{1,m,i,j,k}=\left(\frac{3}{2\Delta t}-\frac{2\mu}{\Delta x^2}-\frac{2\mu}{\Delta y^2}-\frac{\left|u_{i,j,k}^{n+2/3}\right|}{\Delta x}-\frac{\left|v_{i,j,k}^{n+2/3}\right|}{\Delta y}-\frac{\left|w_{i,j,k}^{n+2/3}\right|}{2\Delta z}\right)\theta_{1,m,i,j,k}^{n+2/3}+$$
$$+\left(\frac{\mu}{\Delta x^2}+\frac{u_{i-1,j,k}^{n+2/3}+\left|u_{i-1,j,k}^{n+2/3}\right|}{2\Delta x}\right)\theta_{1,m,i-1,j,k}^{n+2/3}+\left(\frac{\mu}{\Delta x^2}-\frac{u_{i+1,j,k}^{n+2/3}-\left|u_{i+1,j,k}^{n+2/3}\right|}{2\Delta x}\right)\theta_{1,m,i+1,j,k}^{n+2/3}+$$
$$+\left(\frac{\mu}{\Delta y^2}+\frac{v_{i,j-1,k}^{n+2/3}+\left|v_{i,j-1,k}^{n+2/3}\right|}{2\Delta y}\right)\theta_{1,m,i,j-1,k}^{n+2/3}+\left(\frac{\mu}{\Delta y^2}-\frac{v_{i,j+1,k}^{n+2/3}-\left|v_{i,j+1,k}^{n+2/3}\right|}{2\Delta y}\right)\theta_{1,m,i,j+1,k}^{n+2/3}+$$
$$+\left(\frac{w_{i,j,k-1}^{n+2/3}+\left|w_{i,j,k-1}^{n+2/3}\right|}{4\Delta z}\right)\theta_{i,j,k-1}^{n+2/3}+\left(\frac{3}{2\Delta t}-\frac{w_{i,j,k+1}^{n+2/3}-\left|w_{i,j,k+1}^{n+2/3}\right|}{4\Delta z}\right)\theta_{1,m,i,j,k+1}^{n+2/3}+$$
$$+\frac{1}{3}\left(\delta_{i,j,k}F_{gas}-P_{nucl}-P_{cond}\right).$$

$$\bar{\bar{\alpha}}_{1,m,i,j,0} = \frac{4\kappa_1 \bar{\bar{c}}_{1,m,i,j,1} - \bar{\bar{b}}_{1,m,i,j,1}\kappa_1}{3\kappa_1 \bar{\bar{c}}_{1,m,i,j,1} - \bar{\bar{a}}_{1,m,i,j,1}\kappa_1 - 2\Delta z \beta \bar{\bar{c}}_{1,m,i,j,1}};$$

$$\bar{\bar{\beta}}_{1,m,i,j,0} = \frac{\bar{\bar{d}}_{1,m,i,j,1}\kappa_1 + 2\Delta z \bar{\bar{c}}_{1,m,i,j,1} f_0}{3\kappa_1 \bar{\bar{c}}_{1,m,i,j,1} - \bar{\bar{a}}_{1,m,i,j,1}\kappa_1 - 2\Delta z \beta \bar{\bar{c}}_{1,m,i,j,1}}.$$

$$\theta^{n+1}_{1,m,i,j,L} = \frac{2\Delta z \xi \theta_E - \left(\bar{\bar{\beta}}_{1,m,i,j,L-2} + \bar{\bar{\alpha}}_{1,m,i,j,L-2}\bar{\bar{\beta}}_{1,m,i,j,L-1} - 4\bar{\bar{\beta}}_{1,m,i,j,L-1}\right)\kappa_L}{2\Delta z \xi + \left(\bar{\bar{\alpha}}_{1,m,i,j,L-2}\bar{\bar{\alpha}}_{1,m,i,j,L-1} - 4\bar{\bar{\alpha}}_{1,m,i,j,L-1} + 3\right)\kappa_L}.$$

Xulosa. Xulosa sifatida shuni aytish mumkinki, boshqa mualliflarning ko‘plab tadqiqotlaridan farqli o‘laroq, ushbu ishda zarrachalarning cho‘kish tezligi o‘rganilayotgan jarayonga sezilarli ta’sir ko‘rsatadigan o‘zgaruvchan miqdor sifatida ko‘rib chiqiladi. Shuningdek, hisoblash tajribalari natijasida gazli aralashmalari va zararli mayda aerozollarning atmosferada tarqalish jarayoniga ta’sir etuvchi eng muhim omil ko‘rib chiqilayotgan hududda o‘sayotgan o‘simliklar ekanligi aniqlandi.

Ushbu ishda gidrodinamika qonunlariga asoslangan uch o‘lchovli differensial tenglamalarga asoslangan matematik model taklif etilgan. Masalani yechish uchun vaqt va fazoviy o‘zgaruvchilarga nisbatan yuqori tartibli approksimatsiyaga ega oshkormas ko‘rinishdagi chekli ayirmali sxemadan foydalanib sonli algoritm ishlab chiqilgan.

Dasturiy ta’minot yordamida amalga oshirilgan matematik apparat yordamida muhandislar, ekologlar va tadqiqotchilar uchun amaliy ahamiyatga ega bo‘lgan atmosfera chegara qatlamidagi zararli moddalarning sanoat chiqindilarining fazoviy-vaqt evolyutsiyasini baholash va bashoratlash mumkin.

Olingan natijalar asosida tavsiyalar shakllantirildi va tegishli qarorlar qabul qilish uchun O‘zbekiston Respublikasi Ekologiya va atrof-muhitni muhofaza qilish davlat qo‘mitasining Samarqand viloyati bo‘limiga taqdim etildi.

Foydalanilgan adabiyotlar

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