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ZAGAĐENJE VAZDUHA I NJEGOV UTICAJ NA ZDRAVLJE LJUDI: PREGLED STANJA U REPUBLICI SRBIJI

Sažetak: Zagađenje vazduha predstavlja alarmantan globalni izazov koji duboko utiče na zdravlje čovečanstva širom sveta. Među najznačajnijim zagađivačima vazduha su suspendovane čestice, sumpor-dioksid, oksidi azota, teški metali i amonijak, a njihov uticaj na ljudsko zdravlje je ozbiljan i opsežan. Respiratorne bolesti, uključujući astmu, hroničnu opstruktivnu bolest pluća i upalu pluća, često su povezane sa zagađenjem vazduha, dok se povećava i rizik od razvoja drugih ozbiljnih bolesti, poput dijabetesa i kardiovaskularnih problema. Posebna briga leži u izloženosti dece zagađenju vazduha, budući da njihov imuni sistem nije potpuno razvijen, a provode više vremena napolju, gde su koncentracije zagađenja obično više. U Srbiji, kao i u mnogim drugim zemljama, neophodno je preduzeti integrirane međusektorske mere kako bi se smanjilo zagađenje vazduha i zaštitilo zdravlje građana. Ovaj rad ima za cilj pružiti osnovni pregled problema zagađenja vazduha u Srbiji i istražiti mere kontrole i merenja kako bi se bolje razumeli osnovni koncepti i napredovalo u rešavanju ovog ozbiljnog problema.

Ključne reči: Zagađenje vazduha, rizik, svest, javno zdravlje, prevencija

Abstract: Air pollution has become a major global concern with profound implications for public health worldwide. Among the most significant air pollutants are particulate matter, sulfur dioxide, nitrogen oxides, heavy metals, and ammonia, which have serious and wide-ranging effects on human health. Respiratory diseases, including asthma, chronic obstructive pulmonary disease (COPD), and pneumonia, are

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frequently associated with air pollution, while the risk of developing other serious conditions such as diabetes and cardiovascular problems is also elevated. Of particular concern is the exposure of children to air pollution, as their immune systems are not fully developed, and they spend more time outdoors, where pollution concentrations are often higher. In Serbia, as in many other countries, integrated intersectoral measures are necessary to reduce air pollution and protect the health of citizens. This paper aims to provide a basic overview of air pollution issues in Serbia and explore control and measurement measures to better understand the fundamental concepts and make progress in addressing this serious problem.

Key words: Air pollution, risk, awareness, public health, prevention

UVOD

Zagađenje vazduha je problem koji sve više privlači pažnju javnosti, posebno tokom grejne sezone. Prema podacima Svetske zdravstvene organizacije (SZO) iz 2019. godine, čak 99% svetske populacije živelo je na mestima gde nisu ispunjeni standardi za kvalitet vazduha propisani od strane SZO. Širom sveta, zagađenje vazduha u gradskim i ruralnim sredinama bilo je povezano sa čak 4.200.000 prevremenih smrti u 2016. godini. Značajan deo ovih smrtnih slučajeva zadesio je stanovnike zemalja sa niskim i srednjim prihodima, sa najvećim brojem u regionima jugoistočne Azije i zapadnog Pacifika (1).

U kontekstu Srbije, procenjuje se da godišnje oko 6.592 ljudi gubi život zbog posledica izloženosti zagađenom vazduhu (2). Međutim, dodatne procene SZO ukazuju na još alarmantnije brojke kada se uzmu u obzir i posledice zagađenja vazduha unutar domaćinstava. Prema tim procenama, broj prevremenih smrti se gotovo udvostručuje, dosežući čak 11.500 godišnjih smrtnih slučajeva tokom 2016. godine. Rešavanje ovog ozbiljnog problema zahteva ne samo snažnu saradnju između različitih sektora, već i značajna finansijska ulaganja. Prema procenama Fiskalnog saveta, potrebna ulaganja za rešavanje problema zagađenja vazduha iznose čak 2,4 milijarde eura iz državnog budžeta (3).

Praćenje kvaliteta vazduha igra ključnu ulogu u kontroli i proceni nivoa zagađenja. Takođe omogućava praćenje trendova u kvalitetu vazduha, što je od suštinskog značaja za preduzimanje odgovarajućih mera radi smanjenja koncentracija štetnih materija u vazduhu i zaštite ljudskog zdravlja. Ovi elementi zagađenosti vazduha uključuju suspendovane čestice, sumpor-dioksid, okside azota, amonijak, teške metale i ostale zagađujuće supstance.

Analize i merenja u oblasti ekologije i zdravstva nedvosmisleno ukazuju na zabrinjavajuće nalaze – građani širom Srbije suočavaju se sa ozbiljnim izazovima u vezi sa kvalitetom vazduha koji udišu. Cilj ovog istraživanja je da se dublje razumeju aktuelni problemi i osnovni koncepti vezani za zagađenje vazduha u Srbiji, posebno sa naglaskom na njegov potencijalni uticaj na zdravlje stanovništva. Osim toga, razmotrićemo postojeće mere kontrole zagađenja vazduha i istražiti potrebu za daljim istraživanjem i unapređenjem pristupa u rešavanju ovog izazova.

ELEMENTI ZAGAĐENOSTI VAZDUHA

Suspendovane čestice

Suspendovane čestice (*PM – Particulate Matter*) su sitne čestice koje predstavljaju mešavinu prašine, čađi i dima. Ove čestice su suspendovane u vazduhu kao čvrste čestice ili kao tečne kapljice. Suspendovane čestice predstavljaju jednog od najznačajnijih zagađivača sa veoma štetnim uticajem po ljudsko zdravlje. Zavisno od veličine dele se na PM10 i PM2.5 čestice. Ova podela zasnovana je na veličini čestica, pa su PM2.5 čestice sve one koje su veličine do 2.5 mikrona, dok su PM10 čestice sve one čestice veličine do 10 mikrona (4). Izloženost visokoj koncentraciji suspendovanih čestica dovodi do različitih poremećaja zdravlja, kao što su oboljenja respiratornog sistema, pogoršanje postojećih respiratornih i kardiovaskularnih oboljenja, karcionegeneza (5)

Tabela 1. Različiti standardi za graničnu godišnju vrednost koncentracije suspendovanih PM10 i PM2.5 čestica i dnevnu graničnu vrednost PM10 čestica

	SZO	EU	Srbija
PM_{10} – Granična godišnja vrednost	20 μg/m³	40 μg/m³	40 μg/m³
PM_{10} – Granična dnevna vrednost	50 μg/m³	50 μg/m³ / 35 dana prekoračenja	50 μg/m³ / 35 dana prekoračenja
$PM_{2.5}$ – Godišnja granična vrednost	10 μg/m³	25 μg/m³	25 μg/m³
$PM_{2.5}$ – Dnevna granična vrednost	25 μg/m³ / ne sme da pređe 3 dana godišnje	Nema standard	Nema standard

Izvor: Publikacija energija, klima i životna sredina. Beogradska otvorena škola (6)

Sumpor-dioksid

Sumpor-dioksid (SO_2) je bezbojni gas sa oštrim mirisom i kiselim ukusom. Pripada grupi gasova poznatih kao oksidi sumpora i može se naći u različitim sirovinama, uključujući sirovu naftu, ugalj i rude metala kao što su aluminijum, bakar, cink, olovo i gvožđe. Najveći izvori sumpor-dioksida nastaju tokom sagorevanja fosilnih goriva, poput uglja i nafte, dok se manji procenti emisija javljaju u industriji tokom procesa topljenja metala, proizvodnje celuloze i hartije, i u saobraćaju (7).

Sumpor-dioksid može izazvati iritaciju očiju i respiratornog sistema kod izlaganja visokim koncentracijama, a teže slučajeve mogućih oštećenja pluća. Takođe, i hronična izloženost niskim koncentracijama ovog gasa može prouzrokovati štetu gornjim i donjim delovima respiratornih puteva. U prisustvu drugih zagađujućih supstanci sumporni oksidi mogu postati katalizatori hemijskih reakcija u atmosferi, što dovodi do formiranja sekundarnih suspendovanih čestica (8).

Posebno važno je napomenuti da toksičnost sumpor-dioksida može biti pojačana u uslovima povećane vlažnosti vazduha, jer se tada stvara sumporna (sulfatna) kiselina. Ova kiselina u atmosferi reaguje sa ozonom i vodenom parom, stvarajući sumpornu kiselinu (H_2SO_4) i doprinosi pojavi tzv. kiselih kiša (8). Kisela kiša ili „atmosferski talog" formira se kada slobodni nemetalni oksidi sumpora i azota interaguju sa vodenom parom u atmosferi i padaju na zemlju (8).

Ovi procesi imaju duboko ukorenjene ekološke i zdravstvene implikacije koje zahtevaju pažljivo praćenje i regulaciju kako bi se zaštitila životna sredina i zdravlje ljudi.

Oksidi azota

Azot-dioksid (NO_2) je gas koji spada u grupu oksida azota i nastaje tokom nepotpunog sagorevanja goriva, pretežno u saobraćaju i termoelektranama. U urbanim sredinama najveći izvor ovog gasa je sagorevanje goriva, što ga čini tipičnim pokazateljem zagađenja vazduha izazvanog saobraćajem. Osim NO_2, u vazduhu se nalazi još sedam oksida azota, uključujući NO, NO_2, N_2O, NO_3, N_2O_3 i N_2O_5, kao i azotne kiseline (HNO_2, HNO_3) i različita organska jedinjenja azota, kao što su peroksiacil-nitrat (PAN) i drugi organski nitrati.

Zdravstveni rizik povezan sa oksidima azota proizlazi kako iz samih oksida azota, tako i iz njihovih reakcija i uticaja na stvaranje drugih štetnih supstanci. Prisustvo NO2 u vazduhu doprinosi formiranju ozona, suspendovanih čestica i kiselih kiša. U tom smislu, ukupan štetan uticaj oksida azota je teško kvantifikovati i može potencijalno biti obimniji od direktnih negativnih posledica po zdravlje ljudi (9).

Nastojanje da se razume kompleksan uticaj oksida azota na kvalitet vazduha i zdravlje ljudi zahteva interdisciplinarni pristup i kontinuirano praćenje kako bi se identifikovali i kontrolisali rizici povezani sa ovim zagađujućim materijama (9).

Amonijak

Amonijak (NH_3) prisutan u ambijentalnom vazduhu se već duže vreme smatra odgovornim za procese eutrofikacije i acidifikacije ekoloških sistema. Odnedavno je prihvaćen naučni stav da amonijak ima primarnu ulogu u formiranju sekundarnih čestica, stupanjem u brzu reakciju sa već prisutnim kiselim komponentama u ambijentalnom vazduhu (sumpor-dioksid i različiti oblici oksida azota).

Teški metali

Olovo (Pb) je toksični metal. Emisija olova najvećim delom je posledica korišćenja jedinjenja olova kao aditiva u benzinu. Po nekim procenama, od 1923. godine, kada je tetraetil-olovo prvi put dodat benzinu, pa do danas, emitovano je preko četiri milijarde tona olova. Koncentracije olova u ambijentalnom vazduhu su uglavnom niske i kreću se oko 0,1 $\mu g/ m^3$ u zemljama gde se koristi bezolovni benzin do 1 $\mu g/ m^3$, ali mogu da idu i do 10 $\mu g/ m^3$ i značajno zavise od ekonomskog razvoja zemlje, nivoa urbanizacije i načina života.

Ostali elementi zagađenja vazduha

Kadmijum (Cd) je široko rasprostranjen teški metal čiji su glavni antropogeni izvori sagorevanje fosilnih goriva, metalo-prerađivačka industrija, industrija boja, baterija i industrija duvana. U vazduhu se često javlja u obliku mikroskopskih čestica koje se brzo šire izvan izvora emisije, pokrivajući velika područja.

Nikl (Ni) je još jedan teški metal koji se često nalazi u prirodi i ima antropogene izvore u gradovima, uključujući sagorevanje fosilnih goriva, metalurgiju i incineratore. Prema podacima Svetske zdravstvene organizacije, koncentracije nikla u ambijentalnom vazduhu evropskih gradova variraju između 9 i 60 ng/m^3.

Ozon (O_3) se formira u donjim slojevima atmosfere kao sekundarni polutant pod uticajem ultraljubičastog zračenja i često se naziva „loš” ili troposferski ozon. On je izuzetno reaktivan i funkcioniše kao snažno oksidaciono sredstvo. Troposferski ozon igra ključnu ulogu u stvaranju letnjeg smoga. Dugotrajna izloženost zagađivačima vazduha koji sadrže ozon, posebno u saobraćaju, može povećati rizik od pojave astme, naročito kod dece (10).

UTICAJ ZAGAĐENOG VAZDUHA NA ZDRAVLJE LJUDI

Zagađenje vazduha ima ozbiljne posledice na respiratorno zdravlje ljudi i doprinosi širokom spektru oboljenja, uključujući astmu, hroničnu opstruktivnu bolest pluća, upale pluća i tuberkulozu, kao i alergijske bolesti. Iako su veze između zagađenja vazduha i ovih bolesti kompleksne, nedavne epidemiološke studije ističu rastuću važnost zagađenja vazduha, posebno onog povezanog sa saobraćajem, kako u razvijenim tako i u manje razvijenim zemljama. Saobraćaj na lokalnim putevima posebno može ukazivati na štetne efekte zagađenja vazduha (11).

Zagađivači vazduha koji potiču iz saobraćaja i drugih izvora izlažu pojedince kompleksnim mešavinama zagađivača koje karakterišu promenljive koncentracije u prostoru i vremenu. Ovi faktori predstavljaju izazov za tačno kvantifikovanje izloženosti. Međutim, nove metode merenja i modelovanja omogućavaju dublje razumevanje veza između izloženosti zagađivačima vazduha i bolesti respiratornog trakta (12). Dugotrajna izloženost saobraćajnom zagađenju može skratiti očekivani životni vek (13).

Pored direktne štete po ljudsko zdravlje, zagađenje vazduha takođe ima indirektne efekte, uključujući:

- Štetu na poljoprivrednim kulturama i vegetaciji zbog taloženja kiselih supstanci u zemljištu (kiselost tla).
- Trovanje domaćih životinja zbog prisustva teških metala u zemljištu i atmosferskim padavinama.
- Zagađivanje zemljišta i podzemnih voda usled ispiranja štetnih supstanci iz atmosferskih padavina.
- Uticaj na klimatske i mikroklimatske uslove.

Zagađivači vazduha imaju nizak uticaj samo na respiratorno zdravlje, već i na kardiovaskularni sistem (14). Čestice i gasovi prisutni u zagađenom vazduhu mogu izazvati akutne događaje kao što su srčani udar, moždani udar, srčana insuficijencija i hipertenzija (15). Dokazi pokazuju da PM2,5 čestice imaju štetne efekte na kardiovaskularni sistem, doprinoseći aterosklerozi, trombozi, upali i drugim patološkim procesima na koronarnim arterijama, srčanoj insuficijenciji, hipertenziji, dijabetesu i aritmijama (16). Povećanje nivoa zagađenja vazduha tokom poslednjih decenija povezuje se sa 14% svih smrtnih slučajeva usled cerebrovaskularnih bolesti (17). Dostupni dokazi takođe podržavaju vezu između glavnih zagađivača vazduha i povećanog rizika od razvoja dijabetesa melitusa tip 2 (18).

Uticaj zagađenja vazduha na zdravlje dece

Uticaj zagađenja vazduha na decu predstavlja posebno zabrinjavajuću temu, jer su deca izložena zagađivačima vazduha u vreme kada njihov imunološki sistem nije u potpunosti razvijen, što čini njihove organizme podložnijim negativnim efektima. Osim toga, deca često provode više vremena napolju, gde su koncentracije zagađivača, naročito onih iz saobraćaja, elektrana i drugih izvora sagorevanja, obično veće (19)

Nedavna istraživanja ističu ozbiljne posledice zagađenja vazduha na decu. Zagađenje vazduha, posebno ono povezano sa saobraćajem, povezuje se sa povećanom smrtnošću među novorođenčadi i povećanim rizikom od razvoja respiratornih problema, kao što je astma, kao i atopijskih bolesti (19)

Iako mnoge od ovih veza između zagađenja vazduha i zdravstvenih problema kod dece deluju kao uzročne, važno je napomenuti da postoje i drugi faktori koji mogu doprineti ovim efektima. Zbog toga se kontinuirano istražuju kako bi se potvrdile ove veze i razumeli mehanizmi koji leže u osnovi tih efekata. Takođe, ovakva istraživanja pružaju osnovu za razvoj strategija i politika usmerenih na zaštitu dečjeg zdravlja od negativnih uticaja zagađenja vazduha (19).

ZAHTEVI I STANDARDI KVALITETA VAZDUHA U SRBIJI

Zahtevi i standardi za kvalitet vazduha detaljno su definisani Uredbom o uslovima monitoringa i zahtevima kvaliteta vazduha (20). Ova uredba precizira niz ključnih elemenata vezanih za praćenje i kontrolu kvaliteta vazduha. Prema ovom zakonodavnom okviru, postavljaju se specifični kriterijumi za definisanje minimalnog broja mernih tačaka i lokacija za uzimanje uzoraka, metodologiju merenja i ocenjivanja kvaliteta vazduha (uključujući referentne metode merenja i kriterijume za procenu koncentracija zagađujućih materija), zahtevi u vezi sa podacima koji se koriste za ocenjivanje kvaliteta vazduha, način obezbeđenja kvaliteta podataka koji se koriste za procenu kvaliteta vazduha, i opseg i sadržaj informacija koje se odnose na ocenu kvaliteta vazduha u skladu sa Zakonom o zaštiti vazduha (21).

Zahtevi kvaliteta vazduha obuhvataju različite aspekte, uključujući granične vrednosti nivoa zagađujućih materija u vazduhu, gornje i donje granice za ocenjivanje nivoa zagađujućih materija u vazduhu, granice tolerancije i tolerantne vrednosti, koncentracije opasne po zdravlje ljudi i koncentracije o kojima se izveštava javnost, kritične nivoe zagađujućih materija u vazduhu, ciljne vrednosti i (nacionalne) dugoročne ciljeve zagađujućih materija u vazduhu, i rokove za postizanje graničnih i/ili ciljnih vrednosti, posebno u slučajevima kada se one prekorače u skladu sa Zakonom (21). Praćenje nivoa zagađenosti vazduha vrši se merenjem koncentracija različitih zagađujućih materija, kao što su sumpor-dioksid, azot-dioksid, oksidi azota, suspendovane čestice (PM10, PM2.5), olovo, benzen, ugljen-monoksid, prizemni ozon, arzen, kadmijum, živa, nikl i benzo(a) piren u vazduhu. Ovo se postiže korišćenjem automatskih mernih instrumenata i/ili uzorkovanjem vazduha i analizom uzoraka.

STANJE KVALITETA VAZDUHA U SRBIJI

Prema Zakonu o zaštiti vazduha (21), izradu Godišnjeg izveštaja o stanju kvaliteta vazduha u Republici Srbiji priprema i objavljuje Agencija za zaštitu životne sredine. Osnovu za monitoring kvaliteta vazduha predstavlja Uredba o utvrđivanju programa kontrole kvaliteta vazduha u državnoj mreži (22). Ovom Uredbom definisane su merne stanice i merna mesta, njihov broj i raspored, kao i zagađujuće materije koje se na njima mere. Godišnjim izveštajem obuhvaćeni su podaci koji su dostavljeni Agenciji od strane institucija koje vrše merenja i učestvuju u monitoringu kvaliteta vazduha na nacionalnom i lokalnom nivou.

Prilikom izrade Izveštaja koriste se podaci iz mreža stanica za kvalitet vazduha Agencije za zaštitu životne sredine, Gradskog zavoda za javno zdravlje Beograd, Pokrajinskog sekretarijata za urbanizam i zaštitu životne sredine Vojvodine, gradova Pančevo, Sremska Mitrovica, Užice, Požarevac, Subotica, Kraljevo i Sombor. Uredba o utvrđivanju zona i aglomeracija (23) utvrđuje 3 zone i osam aglomeracija u Srbiji. Na teritoriji Republike Srbije postoje tri određene zone:

– Zona „Srbija“, koja obuhvata teritoriju Republike Srbije, osim teritorija autonomnih pokrajina, grad Beograd, grad Niš, opštinu Bor, grad Užice, grad Smederevo i opštinu Kosjerić;

– Zona „Vojvodina”, koja obuhvata teritoriju Autonomne Pokrajine Vojvodine, osim teritorije gradova Novi Sad i Pančevo;

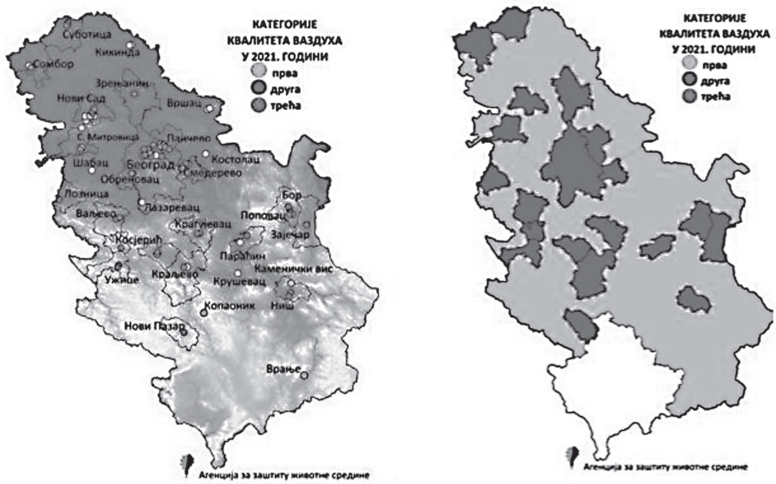
– Zona „Kosovo i Metohija”, koja obuhvata teritoriju Autonomne Pokrajine Kosovo i Metohija.

Na teritoriji Republike Srbije određeno je osam aglomeracija:

– Aglomeracija „Beograd”, koja obuhvata teritoriju grada Beograda;
– Aglomeracija „Novi Sad”, koja obuhvata teritoriju grada Novog Sada;
– Aglomeracija „Niš”, koja obuhvata teritoriju grada Niša;
– Aglomeracija „Bor”, koja obuhvata teritoriju opštine Bor;
– Aglomeracija „Užice”, koja obuhvata teritoriju grada Užica;
– Aglomeracija „Kosjerić”, koja obuhvata teritoriju opštine Kosjerić;
– Aglomeracija „Smederevo”, koja obuhvata teritoriju grada Smedereva;
– Aglomeracija „Pančevo”, koja obuhvata teritoriju grada Pančeva.

U skoro svim od navedenih gradova vazduh je bio prekomerno zagađen usled visoke koncentracije PM10 ili PM 2.5 čestica, sa izuzetkom Bora, koji je svrstan u gradove u najvišoj kategoriji zagađenja usled prekomerne koncentracije sumpor-dioksida (SO_2). Poslednji dostupni izveštaj, za 2021. godinu, koji je Agencija za zaštitu životne sredine objavila, pokazuje da je u 2021. godini vazduh bio prekomerno zagađen u sledećim gradovima: Beograd, Niš, Pančevo, Užice, Smederevo, Kosjerić, Bor, Novi Sad, Valjevo, Novi Pazar, Subotica, Kragujevac, Kraljevo, Loznica, Čačak, Zaječar, Paraćin, Sremska Mitrovica, Sombor i Zrenjanin.

Slika 1. Ocena kvaliteta vazduha u R. Srbiji za 2021. godinu



Izvor: Agencija za zaštitu životne sredine (24)

Ukoliko uporedimo podatke u poslednjih 13 godina, koliko postoji i funkcioniše državna mreža za monitoring kvaliteta vazduha, primetno je da se problem sa prekomernim zagađenjem NO_2 redovno javlja u praktično svim većim sredinama, u kojima postoji redovan monitoring čestičnog zagađenja (6).

Tabela 1. Prosečne godišnje koncentracije NO_2 na posmatračkim stanicama u Srbiji

City/Town	2010	2011	2012	2013	2014	2015	Average, 2010–2015
Belgrade	33.2	40.8	43.0	31.5	29.2	34.3	35.3
Obrenovac	NA	16.4	25.8	NA	NA	22.5	21.6
Novi Sad	69.3	61.7	19.0	18.8	NA	NA	42.2
Beočin	NA	NA	NA	24.4	19.1	NA	21.8
Smederevo	16.4	18.8	16.8	13.8	26.6	15.3	18.0
Kragujevac	29.1	53.7	21.5	26.9	NA	29.8	32.2
Užice	44.9	NA	50.6	48.7	32.2	38.4	43.0
Kosjerić	NA	16.4	18.8	12.9	NA	NA	16.0
Niš	36.4	23.2	33.3	25.9	21.8	26.0	27.8
Valjevo	30.9	18.9	28.3	34.2	21.7	20.7	25.8

Izvor: SZO (2)

Institut za javno zdravlje Srbije „Dr Milan Jovanović Batut“ u svojoj godišnjoj analizi, pod nazivom „Zagađenost urbanog vazduha na teritoriji Republike Srbije merena u mreži institucija javnog zdravlja u 2019. godini“, navodi da je nastavljen trend male zastupljenosti monitoringa čestičnog zagađenja sa česticama tipa PM10 i PM2.5 (20).

MERE PREVENCIJE

Postoje mnoge politike i pristupi u različitim sektorima koji bi mogli značajno doprineti smanjenju zagađenja vazduha. Na primer, u sektoru industrije, primena čistih tehnologija za smanjenje emisija iz dimnjaka i unapređenje upravljanja otpadom, uključujući hvatanje metanskog gasa koji se emituje sa lokacija za odlaganje, može značajno smanjiti izduvne emisije.

U sektoru energetike, obezbeđivanje pristupa pristupačnoj i čistoj energiji za potrebe kuvanja, grejanja i osvetljenja domaćinstava može značajno doprineti smanjenju emisija. Prenos na čistije načine proizvodnje električne energije, kao i podrška javnom prevozu u urbanim područjima, razvoj pešačkih i biciklističkih staza, kao i međugradske železničke veze, takođe su koraci ka smanjenju zagađenja izazvanog saobraćajem.

Urbanističko planiranje može doprineti poboljšanju energetske efikasnosti zgrada i kreiranju energetski efikasnijih gradova kroz strategije koje promovišu zelenije i kompaktnije urbanističke koncepte. Takođe, pažljivo planiranje institucija, poput škola, igrališta i bolnica, može doprineti smanjenju potrošnje energije.

U sektoru proizvodnje električne energije, povećanje upotrebe niskokarbonskih i obnovljivih izvora energije, kao što su solarna energija, energija vetra i hidroenergija, može značajno smanjiti emisije. Ko-generacija toplote i energije, kao i distribuirana proizvodnja energije, kao što su minimreže i solarna proizvodnja na krovovima, mogu doprineti diversifikaciji izvora energije i smanjenju emisija iz sektora električne energije.

U upravljanju komunalnim i poljoprivrednim otpadom, strategije za smanjenje otpada, odvajanje, recikliranje i ponovna upotreba ili obrada mogu smanjiti količinu otpada koji završava na deponijama. Takođe, unapređenje metoda za upravljanje biološkim otpadom i, u slučaju spaljivanja, primena najboljih dostupnih tehnologija, uz strog nadzor emisija, mogu doprineti smanjenju negativnih uticaja na vazduh. Ove različite politike i mere mogu značajno poboljšati kvalitet vazduha i smanjiti negativne posledice po zdravlje i životnu sredina (2).

Postoji niz potencijalnih intervencija koje bi direktno doprinele smanjenju zagađenja vazduha i izloženosti građana. Prvo, smanjenje upotrebe čvrstih goriva za grejanje i kuvanje u domaćinstvima je ključna mera. Takođe, smanjenje emisija iz industrijskih postrojenja igra značajnu ulogu u smanjenju izduvnih gasova.

Prelazak na održiviju mobilnost, kao što je korišćenje čistih oblika prevoza, prioritetni je korak u smanjenju emisija iz saobraćaja. Poboljšanje planiranja gradova i zgrada, kako bi postali energetski efikasniji, zeleniji i kompaktniji, takođe bi doprinelo smanjenju potrošnje energije i emisija. Povećanje upotrebe niskoemisionih goriva i obnovljivih izvora energije bez sagorevanja, kao što su solarne i vetrovite energije, ima potencijal da značajno smanji emisije iz sektora proizvodnje energije. Strategije za smanjenje otpada, odvajanje, reciklažu i ponovnu upotrebu takođe su od suštinskog značaja u smanjenju zagađenja. Unapređenje komunikacije i podizanje svesti o rizicima povezanim sa zagađenjem vazduha mogu doprineti boljem razumevanju problema i podršci za implementaciju mera. Sve ove akcije trebalo bi da budu integrisane u okvir za praćenje životne sredine. Politike za smanjenje zagađenja vazduha treba da se razmatraju kao prilika za međusektorski pristup upravljanju kvalitetom vazduha, sa zajedničkim ciljevima i koordinisanim intervencijama relevantnih sektora, uključujući energetiku, transport, upravljanje otpadom i poljoprivredu.

Druga grupa potencijalnih akcija obuhvata izgradnju kapaciteta stručnjaka za javno zdravlje i primenu savremenih metoda za procenu uticaja na zdravlje i rizika po životnu sredinu. To uključuje praćenje i popunjavanje praznina u znanju i epidemiološkim podacima o zagađenju vazduha. Prikladne akcije u ovom kontekstu uključuju povećanje tehničkih kapaciteta na nacionalnom nivou, razvoj nacionalnih strategija za praćenje i mapiranje rizika po životnu sredinu i njihovog uticaja na specifične zdravstvene ishode, kao i sprovođenje epidemiološkog nadzora nad životnom sredinom (2).

ZAKLJUČAK

Borba protiv zagađenja vazduha zahteva integrisanu međusektorsku saradnju i celovit pristup upravljanju kvalitetom vazduha, kako globalno tako i u lokalnom kontekstu. Stanje u Srbiji posebno zahteva pažnju, s obzirom na postojeće izazove u vezi sa zagađenjem vazduha. Koordinisane intervencije u sektorima kao što su transport, energetika, upravljanje otpadom i poljoprivreda su ključne za poboljšanje kvaliteta vazduha i zaštitu zdravlja građana. Uključivanje svih relevantnih aktera, zajedno sa identifikacijom sinergija između mera za smanjenje zagađenja vazduha i smanjenje emisija gasova sa efektom staklene bašte, može maksimizirati zdravstvene koristi i doprineti očuvanju životne sredine u Srbiji i širom sveta. Čist vazduh nije samo pitanje zdravlja, već i ekonomske dobrobiti i kvaliteta života, a ulaganje u politike i akcije za unapređenje kvaliteta vazduha predstavlja neophodan korak ka boljoj budućnosti, kako u Srbiji tako i globalno.

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AIR POLLUTION AND ITS IMPACT ON HUMAN HEALTH: AN OVERVIEW OF THE SITUATION IN THE REPUBLIC OF SERBIA

Abstract: Air pollution has become a major global concern with profound implications for public health worldwide. Among the most significant air pollutants are particulate matter, sulfur dioxide, nitrogen oxides, heavy metals, and ammonia, which have serious and wide-ranging effects on human health. Respiratory diseases, including asthma, chronic obstructive pulmonary disease (COPD), and pneumonia, are frequently associated with air pollution, while the risk of developing other serious conditions such as diabetes and cardiovascular problems is also elevated. Of particular concern is the exposure of children to air pollution, as their immune systems are not fully developed, and they spend more time outdoors, where pollution concentrations are often higher. In Serbia, as in many other countries, integrated intersectoral measures are necessary to reduce air pollution and protect the health of citizens. This paper aims to provide a basic overview of air pollution issues in Serbia and explore control and measurement measures to better understand the fundamental concepts and make progress in addressing this serious problem.

Key words: Air pollution, risk, awareness, public health, prevention

Sažetak: Zagađenje vazduha predstavlja alarmantan globalni izazov koji duboko utiče na zdravlje čovečanstva širom sveta. Među najznačajnijim zagađivačima vazduha su suspendovane čestice, sumpor-dioksid, oksidi azota, teški metali i amonijak, a njihov uticaj na ljudsko zdravlje je ozbiljan i opsežan. Respiratorne bolesti, uključujući astmu, hroničnu opstruktivnu bolest pluća i upalu pluća, često su povezane sa zagađenjem vazduha, dok se povećava i rizik od razvoja drugih ozbiljnih bolesti poput dijabetesa i

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kardiovaskularnih problema. Posebna briga leži u izloženosti dece zagađenju vazduha, budući da njihov imuni sistem nije potpuno razvijen, a provode više vremena napolju, gde su koncentracije zagađenja obično više. U Srbiji, kao i u mnogim drugim zemljama, neophodno je preduzeti integrirane međusektorske mere kako bi se smanjilo zagađenje vazduha i zaštitilo zdravlje građana. Ovaj rad ima za cilj pružiti osnovni pregled problema zagađenja vazduha u Srbiji i istražiti mere kontrole i merenja kako bi se bolje razumeli osnovni koncepti i napredovalo u rešavanju ovog ozbiljnog problema.

Ključne reči: zagađenje vazduha, rizik, svest, javno zdravlje, prevencija

INTRODUCTION

Air pollution is a problem that is increasingly capturing public attention, especially during the heating season. According to the World Health Organization (WHO) data from 2019, as much as 99% of the world's population lived in places where air quality standards prescribed by the WHO were not met. Worldwide, air pollution in urban and rural areas was associated with as many as 4.2 million premature deaths in 2016. A significant portion of these fatalities affected residents of low and middle-income countries, with the highest number in the Southeast Asia and Western Pacific regions (1).

In the context of Serbia, it is estimated that approximately 6,592 people lose their lives annually due to the consequences of exposure to polluted air (2). However, additional WHO estimates point to even more alarming figures when considering the consequences of indoor air pollution. According to these estimates, the number of premature deaths nearly doubled, reaching up to 11,500 annual fatalities in 2016. Addressing this serious issue requires not only strong collaboration across different sectors but also significant financial investments. According to the Fiscal Council's estimates, the required investments to tackle air pollution amount to as much as 2.4 billion euros from the state budget (3).

Monitoring air quality plays a crucial role in controlling and assessing pollution levels. It also enables the tracking of trends in air quality, which is essential for taking appropriate measures to reduce concentrations of harmful substances in the air and protect human health. These air pollutants include suspended particles, sulfur dioxide, nitrogen oxides, ammonia, heavy metals, and other pollutants.

Analyses and measurements in the fields of ecology and health unequivocally point to alarming findings – citizens throughout Serbia are facing serious challenges regarding the air quality they breathe. This research aims to gain a deeper understanding of current issues and fundamental concepts related to air pollution in Serbia, with a particular emphasis on its potential impact on public health. Additionally, we will examine existing measures for air pollution control and explore the need for further research and improvement in approaches to addressing this challenge.

AIR POLLUTION ELEMENTS

Particulate Matter

Particulate Matter (PM) refers to fine particles that constitute a mixture of dust, soot, and smoke. These particles are suspended in the air as solid particles or liquid droplets. Particulate Matter is one of the most significant pollutants with a highly detrimental impact on human health. Depending on size, they are classified into PM10 and PM2.5 particles. This classification is based on particle size, where PM2.5 particles are those with a size of up to 2.5 microns, while PM10 particles include those up to 10 microns in size (4). Exposure to high concentrations of particulate matter can lead to various health disorders, such as respiratory system diseases, exacerbation of existing respiratory and cardiovascular diseases, and carcinogenesis (5).

Table 1. Different standards for the annual limit value of particulate matter concentrations (PM10 and PM2.5) and the daily limit value for PM10 particles

	SZO	EU	Srbija
PM_{10} – Granična godišnja vrednost	20 μg/m³	40 μg/m³	40 μg/m³
PM_{10} – Granična dnevna vrednost	50 μg/m³	50 μg/m³ / 35 dana prekoračenja	50 μg/m³ / 35 dana prekoračenja
$PM_{2.5}$ – Godišnja granična vrednost	10 μg/m³	25 μg/m³	25 μg/m³
$PM_{2.5}$ – Dnevna granična vrednost	25 μg/m³ / ne sme da pređe 3 dana godišnje	Nema standard	Nema standard

Source: Publication on Energy, Climate, and the Environment. Belgrade Open School (6)

Sulfur Dioxide

Sulfur dioxide (SO_2) is a colorless gas with a pungent smell and acidic taste. It belongs to the group of gases known as sulfur oxides and can be found in various raw materials, including crude oil, coal, and metal ores such as aluminum, copper, zinc, lead, and iron. The major sources of sulfur dioxide arise during the combustion of fossil fuels such as coal and oil, while smaller percentages of emissions occur in industries during metal smelting processes, pulp and paper production, and transportation (7).

Sulfur dioxide can irritate the eyes and respiratory system when exposed to high concentrations, and severe cases may result in lung damage. Additionally, chronic exposure to low concentrations of this gas can cause harm to the upper and lower respiratory tract. In the presence of other pollutants, sulfur oxides can act as catalysts for chemical reactions in the atmosphere, leading to the formation of secondary particulate matter (8).

It is crucial to note that the toxicity of sulfur dioxide can be enhanced under conditions of increased air humidity, as sulfuric (sulfate) acid is then formed. This acid in the atmosphere reacts with ozone and water vapor, creating sulfuric acid (H_2SO_4) and contributing to the occurrence of so-called acid rain (8). Acid rain or "atmospheric deposition" forms when free non-metallic oxides of sulfur and nitrogen interact with water vapor in the atmosphere and fall to the ground (8).

These processes have deeply rooted ecological and health implications that require careful monitoring and regulation to protect the environment and human health.

Nitrogen Oxides

Nitrogen dioxide (NO_2) is a gas belonging to the group of nitrogen oxides and is produced during incomplete combustion of fuel, mainly in traffic and power plants. In urban environments, the primary source of this gas is fuel combustion, making it a typical indicator of air pollution caused by traffic. In addition to NO_2, the air contains seven other nitrogen oxides, including NO, N_2O, NO_3, N_2O_3, and N_2O_5, as well as nitric acids (HNO_2, HNO_3), and various organic nitrogen compounds such as peroxyacetyl nitrate (PAN) and other organic nitrates.

Health risks associated with nitrogen oxides arise from both the oxides themselves and their reactions, impacting the formation of other harmful substances. The presence of NO_2 in the air contributes to the formation of ozone, particulate matter, and acid rain. In this regard, quantifying the overall harmful impact of nitrogen oxides is challenging and may potentially be more extensive than the direct negative consequences on human health (9).

Efforts to understand the complex impact of nitrogen oxides on air quality and human health require an interdisciplinary approach and continuous monitoring to identify and control risks associated with these pollutants (9).

Ammonia

Ammonia (NH_3) present in ambient air has long been considered responsible for eutrophication and acidification processes in ecological systems. Recently, a scientific consensus has been reached that ammonia plays a primary role in the formation of secondary particles by quickly reacting with already present acidic components in ambient air (sulfur dioxide and various forms of nitrogen oxides).

Heavy Metals

Lead (Pb) is a toxic metal, and lead emissions are mainly a result of using lead compounds as additives in gasoline. According to some estimates, since 1923 when tetraethyl lead was first added to gasoline, over four billion tons of lead have been emitted. Concentrations of lead in ambient air are generally low, ranging from around 0.1 $\mu g/m^3$ in countries using unleaded gasoline to 1 $\mu g/m^3$, but they can go up to 10 $\mu g/m^3$, significantly depending on the country's economic development, level of urbanization, and lifestyle.

Other Air Pollution Elements

Cadmium (Cd) is a widely distributed heavy metal with major anthropogenic sources being the combustion of fossil fuels, metal processing industries, paint industry, battery industry, and tobacco industry. It often occurs in the air as microscopic particles that rapidly spread beyond emission sources, covering large areas.

Nickel (Ni) is another heavy metal commonly found in nature with anthropogenic sources in cities, including the combustion of fossil fuels, metallurgy, and incinerators. According to the World Health Organization, concentrations of nickel in the ambient air of European cities vary between 9 and 60 ng/m^3.

Ozone (O_3) is formed in the lower layers of the atmosphere as a secondary pollutant under the influence of ultraviolet radiation and is often referred to as "bad" or tropospheric ozone. It is extremely reactive and functions as a potent oxidizing agent. Tropospheric ozone plays a crucial role in the formation of summer smog. Prolonged exposure to air pollutants containing ozone, especially in traffic, can increase the risk of asthma, particularly in children (10).

IMPACT OF AIR POLLUTION ON HUMAN HEALTH

Air pollution has serious consequences for human respiratory health and contributes to a wide range of diseases, including asthma, chronic obstructive pulmonary disease (COPD), pneumonia, and tuberculosis, as well as allergic diseases. Although the relationships between air pollution and these diseases are complex, recent epidemiological studies emphasize the growing importance of air pollution, especially that associated with traffic, both in developed and less developed countries. Traffic on local roads, in particular, can indicate the harmful effects of air pollution (11).

Air pollutants originating from traffic and other sources expose individuals to complex mixtures of pollutants characterized by variable concentrations in space and time. These factors pose a challenge for accurate exposure quantification. However, new measurement and modeling methods enable a deeper understanding of the links between exposure to air pollutants and respiratory tract diseases (12). Prolonged exposure to traffic-related pollution can shorten life expectancy (13).

In addition to direct harm to human health, air pollution also has indirect effects, including:

- Damage to crops and vegetation due to the deposition of acidic substances in the soil (soil acidity).
- Poisoning of domestic animals due to the presence of heavy metals in the soil and atmospheric precipitation.
- Soil and groundwater pollution due to the leaching of harmful substances from atmospheric precipitation.
- Influence on climatic and microclimatic conditions.

Air pollutants have a low impact not only on respiratory health but also on the cardiovascular system (14). Particles and gases present in polluted air can trigger acute events such as heart attacks, strokes, heart failure, and hypertension (15). Evidence shows that PM2.5 particles have harmful effects on the cardiovascular system, contributing to atherosclerosis, thrombosis, inflammation, and other pathological processes in coronary arteries, heart failure, hypertension, diabetes, and arrhythmias (16). The increase in air pollution levels in recent decades is associated with 14% of all deaths from cerebrovascular diseases (17). Available evidence also supports a link between major air pollutants and an increased risk of developing type 2 diabetes mellitus (18).

The impact of air pollution on the health of children

The impact of air pollution on the health of children is a particularly concerning topic because children are exposed to air pollutants at a time when their immune systems are not fully developed, making their bodies more susceptible to negative effects. Additionally, children often spend more time outdoors where pollutant concentrations, especially those from traffic, power plants, and other combustion sources, are usually higher (19).

Recent research highlights the serious consequences of air pollution on children. Air pollution, especially that associated with traffic, is linked to increased mortality among newborns and an elevated risk of developing respiratory problems such as asthma and atopic diseases (19). Studies also show lower rates of bronchitis and chronic cough in areas with lower concentrations of airborne particles (19).

While many of these associations between air pollution and health issues in children appear causal, it is important to note that other factors may contribute to these effects. Therefore, ongoing research aims to confirm these links and understand the underlying mechanisms of these effects. Such research also provides a foundation for the development of strategies and policies aimed at protecting children's health from the negative impacts of air pollution (19).

REQUIREMENTS AND AIR QUALITY STANDARDS IN SERBIA

Requirements and standards for air quality are detailed in the Regulation on the Conditions for Monitoring and Air Quality Standards (20). This regulation specifies a range of key elements related to monitoring and controlling air quality. According to this legislative framework, specific criteria are set for defining the minimum number of monitoring points and locations for sampling, measurement methodology, and assessment of air quality (including reference measurement methods and criteria for assessing concentrations of pollutants). It also outlines requirements regarding the data used for air quality assessment, ensuring data quality for air quality assessment, and the scope and content of information related to air quality assessment following the Air Protection Law (21).

Air quality requirements cover various aspects, including limit values for pollutant levels in the air, upper and lower limits for assessing pollutant levels in the air, tolerance limits, and tolerant values. It also includes concentrations hazardous to human health and concentrations reported to the public, critical levels of air pollutants, target values, (national) long-term goals for air pollutant concentrations, and deadlines for achieving limit and/or target values, especially in cases where they are exceeded according to the law (21). Monitoring air pollution levels is carried out by measuring the concentrations of various pollutants such as sulfur dioxide, nitrogen dioxide, nitrogen oxides, particulate matter (PM10, PM2.5), lead, benzene, carbon monoxide, ground-level ozone, arsenic, cadmium, mercury, nickel, and benzo(a) pyrene in the air. This is achieved using automatic measuring instruments and/or air sampling and analysis of samples.

AIR QUALITY STATUS IN SERBIA

According to the Air Protection Law (21), the Annual Report on the State of Air Quality in the Republic of Serbia is prepared and published by the Environmental Protection Agency. The basis for air quality monitoring is the Regulation on the Establishment of the Air Quality Control Program in the State Network

(22). This regulation defines measurement stations and locations, their number, arrangement, and the pollutants measured at these locations. The Annual Report covers data provided to the Agency by institutions conducting measurements and participating in air quality monitoring at the national and local levels.

In preparing the report, data from the air quality monitoring stations of the Environmental Protection Agency, the City Institute of Public Health in Belgrade, the Provincial Secretariat for Urbanism and Environmental Protection of Vojvodina, and the cities of Pančevo, Sremska Mitrovica, Užice, Požarevac, Subotica, Kraljevo, and Sombor are used. The Regulation on the Determination of Zones and Agglomerations (23) establishes three zones and eight agglomerations in Serbia. The three designated zones in the Republic of Serbia are:

– Zone "Serbia", covers the territory of the Republic of Serbia except for the territories of autonomous provinces, the city of Belgrade, the city of Niš, the municipality of Bor, the city of Užice, the city of Smederevo, and the municipality of Kosjerić;

– Zone "Vojvodina", covers the territory of the Autonomous Province of Vojvodina except for the territories of the cities of Novi Sad and Pančevo;

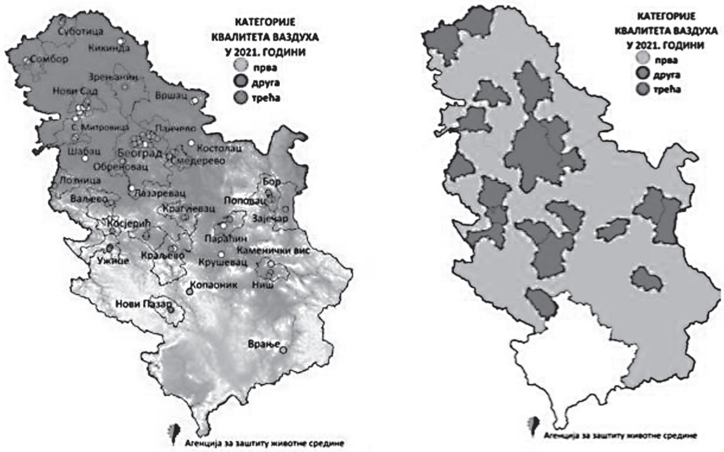
– Zone "Kosovo and Metohija", covers the territory of the Autonomous Province of Kosovo and Metohija.

Eight agglomerations are determined in the territory of the Republic of Serbia:

– Agglomeration "Belgrade", covers the territory of the city of Belgrade;
– Agglomeration "Novi Sad", covers the territory of the city of Novi Sad;
– Agglomeration "Niš", covers the territory of the city of Niš;
– Agglomeration "Bor", covers the territory of the municipality of Bor;
– Agglomeration "Užice", covers the territory of the city of Užice;
– Agglomeration "Kosjerić", covers the territory of the municipality of Kosjerić;
– Agglomeration "Smederevo", covers the territory of the city of Smederevo;
– Agglomeration "Pančevo", covers the territory of the city of Pančevo.

In almost all of the mentioned cities, the air was excessively polluted due to high concentrations of PM10 or PM2.5 particles, except for Bor, which was classified as a city with the highest pollution category due to excessive concentrations of sulfur dioxide (SO_2). The latest available report for the year 2021, published by the Environmental Protection Agency, shows that in 2021, the air was excessively polluted in the following cities: Belgrade, Niš, Pančevo, Užice, Smederevo, Kosjerić, Bor, Novi Sad, Valjevo, Novi Pazar, Subotica, Kragujevac, Kraljevo, Loznica, Čačak, Zaječar, Paraćin, Sremska Mitrovica, Sombor and Zrenjanin.

Figure 1. Air Quality Assessment in the Republic of Serbia for 2021



Source: Environmental Protection Agency (24)

If we compare the data over the last 13 years, the period during which the state network for air quality monitoring has existed and operated, it is noticeable that the issue of excessive NO_2 pollution regularly arises in practically all major environments where regular monitoring of particle pollution is conducted (6).

Table 1. Average annual concentrations of NO_2 at monitoring stations in Serbia

City/Town	2010	2011	2012	2013	2014	2015	Average, 2010–2015
Belgrade	33.2	40.8	43.0	31.5	29.2	34.3	35.3
Obrenovac	NA	16.4	25.8	NA	NA	22.5	21.6
Novi Sad	69.3	61.7	19.0	18.8	NA	NA	42.2
Beočin	NA	NA	NA	24.4	19.1	NA	21.8
Smederevo	16.4	18.8	16.8	13.8	26.6	15.3	18.0
Kragujevac	29.1	53.7	21.5	26.9	NA	29.8	32.2
Užice	44.9	NA	50.6	48.7	32.2	38.4	43.0
Kosjerić	NA	16.4	18.8	12.9	NA	NA	16.0
Niš	36.4	23.2	33.3	25.9	21.8	26.0	27.8
Valjevo	30.9	18.9	28.3	34.2	21.7	20.7	25.8

Source: World Health Organization (2)

The Institute of Public Health of Serbia "Dr. Milan Jovanović Batut," in its annual analysis titled "Urban Air Pollution in the Territory of the Republic of Serbia Measured in the Network of Public Health Institutions in 2019," states that the trend of low representation of particulate pollution monitoring with PM10 and PM2.5 particles continued (20).

PREVENTIVE MEASURES

There are many policies and approaches in various sectors that could significantly contribute to reducing air pollution. For example, in the industrial sector, the implementation of clean technologies to reduce emissions from chimneys and improve waste management, including capturing methane gas emitted from landfill sites, can significantly decrease exhaust emissions.

In the energy sector, providing access to affordable and clean energy for household cooking, heating, and lighting needs can significantly contribute to emission reduction. Transitioning to cleaner methods of electricity production, as well as supporting public transportation in urban areas, developing pedestrian and bicycle paths, and intercity rail connections, are also steps toward reducing pollution caused by transportation.

Urban planning can contribute to improving the energy efficiency of buildings and creating more energy-efficient cities through strategies that promote greener and more compact urban concepts. Additionally, careful planning of institutions such as schools, playgrounds, and hospitals can contribute to reducing energy consumption.

In the power generation sector, increasing the use of low-carbon and renewable energy sources, such as solar energy, wind energy, and hydropower, can significantly reduce emissions. Combined heat and power generation, as well as distributed energy production, such as mini-grids and rooftop solar production, can contribute to diversifying energy sources and reducing emissions from the electricity sector.

In municipal and agricultural waste management, strategies to reduce waste, separate, recycle, and reuse or treat waste can reduce the amount of waste ending up in landfills. Additionally, improving methods for managing organic waste and, in the case of incineration, applying the best available technologies with strict emission control can contribute to reducing negative impacts on the air. These various policies and measures can significantly improve air quality and reduce negative consequences for health and the environment (2).

There is a range of potential interventions that would directly contribute to reducing air pollution and citizens' exposure. Firstly, reducing the use of solid fuels for heating and cooking in households is a key measure. Additionally, reducing emissions from industrial facilities plays a significant role in decreasing exhaust gases.

Transitioning to more sustainable mobility, such as the use of clean transportation modes, is a priority step in reducing emissions from traffic. Improving city and building planning to make them more energy-efficient, greener, and compact would also contribute to reducing energy consumption and emissions. Increasing the use of low-emission fuels and non-combustible renewable energy sources, such as solar and wind energy, has the potential to significantly decrease emissions from the energy production sector. Strategies for waste reduction, separation, recycling, and reuse are also crucial in reducing pollution. Enhancing communication and raising awareness of the risks associated with air pollution can contribute to a better understanding of the issue and support the implementation of measures. All these actions should be integrated into an environmental monitoring framework. Policies to reduce air pollution should be considered as an opportunity for an interdisciplinary approach to air quality management, with shared goals and coordinated interventions across relevant sectors, including energy, transportation, waste management, and agriculture.

The second group of potential actions involves building the capacity of public health experts and applying modern methods to assess health impacts and environmental risks. This includes monitoring and filling gaps in knowledge and epidemiological data on air pollution. Appropriate actions in this context include increasing technical capacities at the national level, developing national strategies for monitoring and mapping environmental risks and their impact on specific health outcomes, as well as implementing epidemiological surveillance of the environment (2).

CONCLUSION

The fight against air pollution requires integrated cross-sectoral collaboration and a comprehensive approach to air quality management, both globally and in the local context. The situation in Serbia particularly demands attention, given the existing challenges related to air pollution. Coordinated interventions in sectors such as transportation, energy, waste management, and agriculture are crucial for improving air quality and protecting the health of citizens. Involving all relevant stakeholders, along with identifying synergies between measures to reduce air pollution and decrease greenhouse gas emissions, can maximize health benefits and contribute to environmental preservation in Serbia and worldwide. Clean air is not only a matter of health but also of economic well-being and quality of life, and investing in policies and actions to enhance air quality is a necessary step towards a better future, both in Serbia and globally.

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