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Ergas SJ, Schroeder E, Chang D, Scow K, (1994) Spatial distributions of microbial populations in biofilters. In: Proceedings of the *78th Annual Meeting and Exhibition of the Air and Waste Management Association*, pp. 19-24, Cincinnati, OH.

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Review Paper

Building Energy Modelling Review

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Abstract: In with parallel to the population growth, the increasing for energy throughout the world causes increase in environmental health problems at the end of energy use have made it necessary to use energy more effectively and efficiently. Reasercher show that most of the energy consumption is caused by buildings. The increase in the buildings with each days causes to Investigate the Inenergy consumption at the same rate. Due to the continuous increase in energy consumption, the global warming and health problems that have become threatening to humanityled to the emergence of the sustainable Building.Sustainable buildings are environmentally friendly structures designed to use energy resources in the most efficient way. In this Review, more effective and environmentally friendly building energy models have become an attractive topic and common in both research and industrial society in recent years. In this study, which aims to evaluate sustainable building in terms of energy efficiency and to determine the criteria that should be found in green building applications; Energy efficiency and Eco- Environment building concepts have been mentioned and a general review has been made on methods of building information modeling (BIM) utilized in building design process for building energy modeling (BEM) process. Finally, explanatory information about a sample energy analysis simulation study to be carried out including use the Design Builder and Energy Plus programs is included.
Keywords: *Sustainable Buildings, Energy Efficiency, Building Information Modeling (BIM), Building Energy Modeling (BEM),*

Introductıon

Due to the worldwide population growth, the rapid growth of national economies and the desire of individuals to have a better quality of life, the energy consumption required for buildings surrounding living spaces is increasing at an eye-catching pace (Kelso, 2012). Factors that adversely affect human life such as environmental pollution, global warming with climate changes that occur due to the increase in energy consumption around the world are gradually increasing. About 40% the energy consumption from buildings. For this reason, the concept of sustainability has been reflected in the building sector over time and has revealed the concept of energy efficient building. Nevertheless, proper design and construction of buildings can reduce their dependence on energy needs. One of the effective ways to achieve this is to use Building Energy Modeling (BEM) technology, which includes alternative and optimized methods in the design of buildings (Al-Homoud, 2001).

Sustainable buildings are certified according to certain standards like reducing energy consumption, being more valuable, more ecological and more comfortable. Energy efficient building designs should be emphasized to achieve energy efficiency in green buildings. Buildings designed with an energy-efficient approach not only provide energy efficiency, but also offer healthy and comfortable environments to their users.

In the field of BIM technology, a new approach has emerged called Building Energy Modeling (BEM). In this method, building models containing design, mechanical load calculations, material properties and information about the heating, ventilation and air conditioning (HVAC) system are used to create inputs to computer programs. With BIM, users are also provided with the opportunity to operate a building design with ease, time savings, low cost, practicality, and an accurate process and consistent. Using BEM, the designerscan better evaluate design selections and make efficient decisions during the design process of building. In this way, the energy efficiency of building goal can be carrying out more easily (Gao et al 2019).

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When BIM is used, computerized information can be the time of consuming, costly, and labor-intensive. This information should also comply with energy standards. Despite all its advantages, it is thought that BIM, which is an energy efficient building modeling tool with digital modeling, is not fully utilized (Ernstrom *et al* 2006).

This article Provides a comprehensive literature review on the developing of the BIM that based on the BEM methods and their use for energy efficient building design, and explains the concept of energy efficiency in buildings and best practices in this context; It includes requirements for the use of building information modeling (BIM) and building energy modeling (BEM) and BIM-based technologies, industry base classes (IFC) and green building studio-based methods in the building design process. In the study, energy modeling simulation tools that are widely used in buildings were examined and a sample application was presented about a future energy analysis simulation study using integrated programs.

Energy Effıcıency In Buldıngs

Increasing global warming together with the gradual decrease of natural resources and clean water resources affected the building sector as well as many other sectors. These passive factors have led the building sector to environmentally friendly and ecological building construction. The increasing of environmentally friendly building construction design has created the concept Building integration method building. Energy efficiency method are certified according to certain standards. Like orientation, a new sector has emerged against buildings that are more ecological, more valuable, more comfortable and less energy consuming (Yonar, 2009**)**. The World Energy Council defines energy efficiency as reducing the amount of energy used for any life activity. Reducing the amount of energy can be achieved with the development of technology, as well as through better structuring and management and raising awareness of people (World Energy Council, 2008).Energy efficiency is also expressed as the use of less energy in a job or production of the same amount or increasing theor production while remaining the same amount of energy without compromising the quality and quantity of production (Olgun et al 2009) According to another definition, energy efficiency is expressed as taking measures to minimize energy losses, ensure the recovery of some wastes and reduce energy demand by using methods such as gas, heat, steam and air without reducing the amount of production (Tevem & Enverder 2010).Today, energy efficiency is most commonly expressed as the most cost-effective and safe type of energy source (Allen et al 2019). Energy efficiency constitutes with of energy transition strategies around the world. Countries prefer to benefit from energy efficiency in terms of cost. Due to the decrease in energy resources and the increase in global warming, the interest shown in energy efficiency is increasing. For this reason, technological developments are continuously transferred to energy systems (Miller et al 2018). Energy efficiency is of great importance in order to be able to interpret the social effects resulting from energy transitions more accurately and to better understand the developments in technology (Sovacool, 2014). There is no internationally accepted standard definition of the carbon footprint. It derives from the concept of ecological footprint. Global warming gases that occur after people's living activities harm the natural environment and human health. The amount of this damage in terms of unit carbon dioxide is expressed as the carbon footprint (Sivri et at 2015). The concept of carbon footprint is divided into two as primary carbon footprint that directly causes greenhouse gas emission and secondary carbon footprint that indirectly causes greenhouse gas emission. The direct carbon dioxide emission resulting from the combustion of fossil fuels consumed in the heating of buildings, in the transportation sector and in the field of energy production represents the primary carbon footprint. Secondary carbon footprint, on the other hand, refers to the indirect carbon dioxide emission released into the atmosphere during the process from the production stage of the substances used by humans throughout their life until they dissolved and change in natüre (Koçer *et al*., 2015).

Energy Efficiency Concept for Buildings

Energy efficiency is defined as electrical energy produced by using renewable energy sources. Compared to nuclear or conventional energy sources, energy efficiency causes less damage to the environment (Rahbauer, et al 2016) and has some advantages (Petrova, 2010) that energy efficiency buildings have little impact on the natural environment when compared to classical buildings (Krygiel, et al 2008). With the use of resources decreases and a more productive and healthy environment is created. Mixture efficient are that provide healthier and more comfortable environments for their users, while reducing the investment cost and allowing the living cost to be minimized (Magent, 2005).

While designing, constructing and using energy efficiency buildings, care is taken to utilize natural resources, energy and water in the most efficient way. They are designed and built to protect the health of the users and increase their efficiency. Economic benefit is one of the most important reasons for choosing a buildings. The high performance of the buildings reduces the operating costs. This makes the buildings more valuable and the life of the building is longer. Studies show that even though the construction of green buildings costs 2% more, it saves 10 times more compared to traditional buildings during the usage period (Sarıer *et al*., 2012).

Research on energy efficiency buildings shows that compared to classical buildings (Ding, 2008):

- Energy savings between 24% and 50%,
- CO2 emission reduction between 33% and 39%,
- 30% to 50% water savings,
- 70% reduction in the amount of solid waste,
- 13% shows that it provides benefits such as low maintenance cost.

Energy efficient Building Implementations

Figures, Tables and Equations should be given in the same page (not separate pages). If any of them is long as a whole page, it should be given into the Appendixes.

Computer Aıded Buldıng Desıgn Examıned (Cat) Process

In this section examined, prominent design strategies and integrated design concept in the design process of building. According of building information modeling (BIM) and building energy modeling (BEM) and development formats that have the characteristics of the buildings were introduced.

Generally, the design process of a building consists of the design of concept, preliminary design, advanced design and detailed of design stages. During the concept of design phase, a project group is formed to determine the needs of the building with stakeholders. At this stage, project objectives and design of the requirements (site orientation, mass & form, the initial services and building system)are determined. Preliminary design, building layout planning, building and material systems created by considering daylight, thermal and energy performance, lighting, comfort design including acoustic and thermal performance, HVAC options, water and waste water systems and fire, etc. Includes security strategies. In the preliminary design, a detailed energy modeling including thermal heat and daylight lighting should also be made. During the design phase, requirements& protocols for the construction plans should be prepared for formal documentation. Documents created include approval at this stage, tender of drawing, specifications, file report for the each of discipline. Documentation must be coordinated across all disciplines, or else the building and the construction of process could be adversely affected (Web 6).

This process starts with a design ofconcept decided by the client and architect. According to this concept, civil, structural, mechanical and electrical engineers are asked to apply the design (Bragança L, et al 2004). In this design process, low performance and the high of operating costs often arise theduring operation, as a result of insufficient use of BIM and BEM for the additional high cost. At the next stage, advanced and high performance of systems emerge with help of building of simulation. However, if there are errors and flaws in the initial designs, the developed high-performance systems may not be able to overcome them (Larsson, 2009).

In building design with integrated systems, architects work as team leaders to incorporate input from other designers. Therefore, engineersare also expected to take initiative on the design concept rather than just doing the design work. It not only manages construction costs, but also performs life cycle analyzes of elements and in corporates the other of technological systems into designs (Zimmerman & Eng, 2006).

Building Information Modelling (BIM)

Building Information Modelling (BIM) has become a necessary technology for the Integrated Design Process (IDP), which can be summed up as various engineers coming together to improve the

Building design process (Filzmoser M, et al 2016). The BIM concept was first introduced by Chuck Eastman in 1974, demonstrating that it can help visualize and quantitatively analyze a building project using computer-based systems (Eastman et al 1974; Fernandez, 2015).

With BIM technologies, which are preferred to reduce building energy consumption, the following can be done: energy simulation for building mass analysis, daylighting and water consumption potential analysis of the building, researching the suitability of sustainable and recycled materials for the building, thus reducing waste and carbon emissions (Wong JKW, & Zhou J,2015).

BIM allows montage of photo to integrate photo realistic project images with conditions of existing. Again, BIM tools can enable 3dimension interior & exterior models, animations, building energy performance and structural analysis (Azhar S, 2011).

There are different team members in building design made with BIM technologies.The members of building project team may include the managers of project, architects, mechanical, electrical and civil engineers specialized in energy simulation, as well as researchers and construction managers (Web 7). With the advent of BIM technology, the building projects can become more efficient and smarter (Guide B,2015).

Building Energy Modelling (BEM)

Building Energy Modeling (BEM) is apowerful computer system used to evaluate the performance of buildings in terms of architectural and mechanical design (Guide, 2015). With BEM, environmental effects are evaluated in the design of buildings and the energy performance of the building is optimized. The energy characteristics and energy consumption of the building and its subsystems can be calculated. Building daylight performance can be evaluated. Alternatives of architectural design features such as energy consumption of the building, thermal comfort, etc. in areas can be researched. In the design phase, it is recommended to take advantage of the advantages provided by BEM to a great extent (Maile, et al 2007).

The features of BIM applications that are widely used in the literature are included in comparison. The most known BEM tools have a user interface that includes regional loads, building envelope, sunlight, ventilation and airflow, climate data, renewable energy systems, electrical systems and environmental emissions, as well as economic evaluation of HVAC systems and reporting of results (Crawley *et al*., 2008).

In the BEM environment, the simulation engine uses input files of a certain format to perform the simulation and produce an output file. The graphical user interface usually processes the output files to show the results of this process in a more graphical way (Maile *et al.,* 2010). In BEM, simulation-specific parameters such as building geometry, thermal of zones, internal of loads, HVAC components, weather are used as inputs (Bahar *et al.,* 2013). To solve building problems in BEM energy modeling predictions, researchers develop dynamic models to predict building energy performance (Menezes AC. *et al*., 2012; Wang *et al*., 2018).

In the final design phase, the building information required for BEM is more detailed. In particular, a more detailed energy model can be created to evaluate multiple building design concepts, including heating, ventilation and air conditioning (HVAC). By comparing the energy performances of various designs, the design team can achieve design optimization to meet final budget requirements (Buonomano & Palombo, 2014). Examples of common BEM tools are eQUEST, Design Builder, Energy Plus, Autodesk Green of Building Studio (GBS), IES Virtual Environmental and Trace 700 (Dong *et al*., 2007).

BIM Data Formats

There are different inputs that affect the capabilities of BEM applications. For example, DOE-2 and BLAST can select a hardware-only HVAC system as input, while in Energy Plus user configurable cooling and heating equipment components make the simulation more flexible in terms of real conditions 9 (Crawley DB, et al 2001). The ideal workflow for simulation tools for BIM-based energy performance is shown in Figure 1 (Maile T, et al 2007). BIM-based BEM tools use a defined format that includes two building properties: Industry base classes (IFC)based methods and green building-based methods.

Industry foundation classes (IFC) data format

Industry Foundation Classes (IFC) is an ISO certified open and standard 3D object-oriented data processing format. It was originally developed by the International Association for Interoperability (IAI) in 1996. IFC was developed for universal use in information sharing in the construction industry (Bazjanac & Crawley, 1997).

Green building XML (gbXML) data format

Green Building XML is a building data format developed by the Autodesk Green of Building Studio company using the Extensible Markup Language (XML) format (Lam *et al*., 2012). Users can pull awell-formed gbXML file from the BIM tools and upload a summary of the simulation results of the building according to some parameters, into the corresponding BEM tools. It was developed mainly with the aim of facilitating data transformation from BIM to the analysis tools of engineering (Gourlis & Kovacic, 2017).

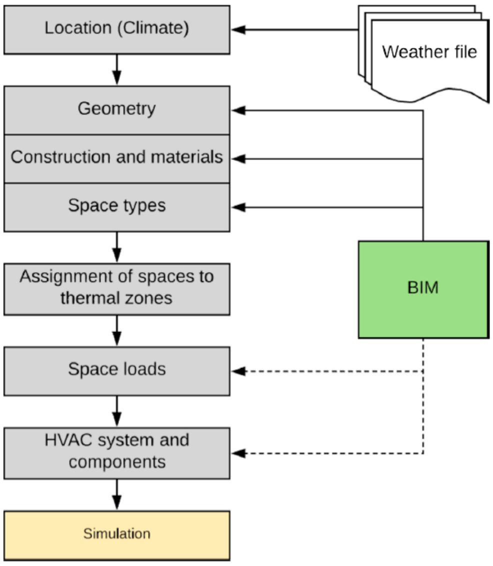

Figure 1. Workflow for performance of energy simulation tools

Commonly Used Building's Energy Modelling Simulation Tools

The historical background of the simulation tools developed for the analysis of buildings goes back to the 1970s. In this process, many simulation programs with different features have been developed. These simulation programs are developed in accordance with their own energy and building standards in many countries, as well as designed with flexibility suitable for international use (Tunali, 2012).

The basic theory of these tools is based on the calculation of the loads of performance parameters such as heating ventilation and air conditioning and the required energy. Simulation programs for calculating thermal-based dynamic interaction associated with user comfort and energy consumption, including building envelopes, HVAC systems, lighting and solar control elements, usually perform separate load calculations for each zone on an hourly basis (Hong et al., 2000).

Comparison of Energy Analysis Tools

In this part of the study, prominent features such as supported data formats have been examined by simulation. These programs are in alphabetical order; ArchiCAD, DOE-2, Ecotect, Energy-10, Energy Plus, EQUEST, ESP-r, Green Building Studio, IES-VE, Lumion, OpenStudio, Revit, Sketch Up, TRACE 700, TRNSYS. HAP, IES, VS.

Design Builder

It is one of the most important simulation programs used for energy modeling. This program is an interface program that works in conjunction with the "Energy Plus" simulation program, which is constantly updated by the United States Department of Energy. Design Builder stands out with its easy-to-understand and easy-to-use interface and system diversity. The Design Builder, used to developed for energy, carbon emissions, lighting and comfort control in the building, the DWG files with Energy Plus axillary weather program (Kayın, 2019).

,
DOE-2

It is an energy performance simulation program that calculates energy performance and operating life cost of the entire building with hourly data. Hourly climate data, information have by insert the location and direction of the building, building element and material information, have by insert properties the usage process diagram of the building, service systems data, component prices are entered as input data to the program. 50 different monthly or annual summary reports, analysis reports of 700 different energy variables per hour depending on user configuration are presented as output data. Strengths: It can perform detailed hourly energy analysis even in the most complex buildings. Weaknesses: Due to its complex interface and usage, the user must have a command of the program in order to get the right results. In addition, the program is not supported in recent years, new technology developments are not updated within the program. Since it is written in an old scripting language like Fortran, it runs slower than other programs. Instead of this program, EnergyPlus was developed by combining the features of Blast and DOE (Tunali, 2012).

Eco Designer

Basically, it is a 3D CAD (Computer Aided Design) software produced by Graph iSOFT for architects. This technology allows architects to perform reliable dynamic energy evaluation of their BIM model within Archibald. With Archibald's built-in Eco Designer STAR or Sun Study module, energy analyzes can be easily performed on BIM models to obtain the best performing design. It has its used interface to own energy modeling user interface. Linking to other programs can be established via the Archibald-Grasshopper link or a model export solution. Successful results on energy consumption, carbon footprint and monthly energy balance can be achieved with Eco Designer (Web 1).

Ecotect

It is a commercial program owned by Autodesk. Its visual properties have improved. It combines a 3D building modeling interface with solar, thermal, lighting, acoustics, and cost analysis functions. It has features that will allow the building to be developed in terms of energy and environmental performance, especially during the conceptual design phase. It has a holistic approach that helps engineers design low energy buildings. It can work in collaboration with other building energy analysis programs. Complex 3D CAD models can be included in the program in a simplified form. It can also be used as input data for 3DS and DXF files. Analysis results can be saved as Meta, Bitmaps or visual animations, or presented graphically. Even with a very simple model, basic energy analysis can be made, guiding the users to the design from the first stages of the design. They provide ease of decision-making for the user in complex system solutions with detailed modeling in the final stages of design. Its weaknesses are that since the program has a detailed software in itself, the user must have a command of the program, otherwise the results obtained may mislead the designer (Tunali, 2012).

Energy Plus

Energy Plus is mostly simulation tools used. Basically it is just a simulation tool and by inputs and outputs simple text files. It does not have an improved user interface, but there are interfaces developed by commercial companies. It can perform precise calculations even for complex structures with time steps of less than an hour. In addition to the energy profiles of the building, conditions such as air flow, fuel cells and electrical energy simulation, distributed energy systems, water use can also be modeled for multi-zone situations with the recently added features. The fact that the input data is in the form of text makes it difficult to use compared to other programs with graphical interfaces (Kayın, 2019).

EQUEST

It is an advanced simulation tool for energy performance analysis that is widely used. The building design with high energy performance with easy-to-use interfaces, continuously updated library and parametric analysis in the design process, starting from the first stages of the design to the last stage. Many different levels of input data are used, including schematic design wizard, design development wizard and detailed (DOE-2) interface. The input data in all these interfaces are transferred from the library in the program to the model. Floor-coupling, infiltration and natural ventilation models are simple and limited (Tunali, 2012).

Green Building Studio (GBS)

Green Building Studio was developed by Autodesk. It is a cloud-based service that provides flexibility to the design process in simulation tools used to optimize energy efficiency. It helps to develop high-performance building design skills in a shorter time and lower cost than traditional methods. A Revit building model scraped for energy analysis is packaged in a gbXML file and submitted to Autodesk Green Building Studio for analysis (Web 2).

IES-VE

IES-VE is a simulation program used in energy efficient building design for environmentally friendly building design. It can perform analysis in the design of heating, cooling, and ventilation systems such as indoor climate assessment and energy consumption calculation. Hourly climate data, building element and material information, usage process diagram of the building, service systems data, component prices are entered as input data to the program. Users can obtain the energy consumption data calculated individually, hourly, weekly, monthly or periodically for each zone in the form of a table or graph. It is a program that is constantly developed and updated, but it is more effective in small-scale structures (Tunali, 2012).

Open Studio

The open of Studio is a simulation tool developed by Energy Plus to run on Windows, Mac and Linux. Open Studio is an open source (LGPL) project. It includes the interfaces of graphical along with the Software Development Kit (SDK). Open Studio Sketch Up Plugin is an extension that allows users to create the geometry needed for Energy Plus. Supports importing of gbXML and IFC for geometry rendering. It is a full featured graphical interface including HVAC. It allows to plot and compare simulation outputs containing time series (Web 3).

RIUSKA

RIUSKA is an integrated simulation tool that can be used in the building design process. The program covers the simulation of the entire building life cycle, from preliminary design to renovations. The main components of the system; database, calculation engine and results module. With RIUSKA, users can add building envelope materials, internal loads and HVAC system to the 3D model of the building and perform thermal calculations. RIUSKA & SMOG offers different outputs for different needs during the design process (Jokela et al., 1997).

TRACE 700

TRACE 700 stands for Trane Air Conditioning Economy. TRACE 700 is a Windows-based program for creating virtual buildings, calculating air conditioning loads. It can also perform life-cycle cost analysis. TRACE 700 helps optimize the building's heating, ventilation and air conditioning system based on energy use. TRACE 700 has a simple interface, but has limited capabilities (Web 4; Web 5).

TRNSYS 17

TRNSYS consists of a graphical interface and simulation engine, and a library containing many building components, HVAC system components and renewable energy technology. It also makes it possible to define new components that are not included in the library. For over 30 years, it has been used for HVAC analysis and dimensioning, multi-zone air flow analysis, electrical simulation, solar design and building thermal performance, analysis and control calculations. Due to its modular structure, TRNSYS offers flexibility in modeling energy systems of various complexity levels. Provides access to software code and documentation, allowing the user to make arrangements that allow the user to easily define outside the standard library (Harputlugil, 2014).

Studies in The Literature

Recently, many of the researchers have attempted to develop the BIM that based BEM applications using IFC and GBXML based methods. In this part of the study, it has been mentioned about the studies conducted using these programs in the literature. Studies examining BIM-based BEM applications focused to the geometry and material properties of the building using IFC. Energy Plus, Open Studio, DOE-2, TRNSYS, and Archibald are the best-known tools for BIM/BEM for IFC. Some studies using the IFC method are shown in Table 1 (Cormier A, et al 2011; Pinheiro et al 2016).

Table 1. Research using IFC based methods

Author	Year	Development Level	BIM	BEM
Cormier et al.	2011	Geometry, Material	Revit ArchiCAD	TRNSYS,Energy Plus
Ramaji et al.	2012	Geometry, Material	IFC-compliant BIM	OpenStudio
Kim and Yu	2016	Geometry, Material	ArchiCAD	DOE-2
Bazjanac and Maile	2004	Geometry, HVAC	IFC-compliant BIM	Energy Plus
O'Sullivan and Keane	2005	Geometry, HVAC	ArchiCAD	Energy Plus
Pinheiro et al.	2016	HVAC	Revit	--

The most up-to-date and popular BIM/BEM software using GBXML are Revit, Archibald, Energy Plus, e-QUEST, IES-VE and Green Building Studio particularly building energy analysis. Some studies using the GBXML method are shown in Table 2 (Rahmani Asl M, et al 2013; Amor R, et al 2014).

Table 2. Researches using gbXML based methods

Author	Year	Development Level	BIM	BEM
Garcia and Zhu	2014	Geometry, Material	Revit	eQUEST
Che et al.	2010	Geometry, Thermal Zone	Revit	IES-VE
Rahmani et al.	2013	Geometry, T. Zone	Revit	Green Building Studio
Ali	2010	Geometry, Material, T. Zone	Revit	Trace
Dimitriou et al.	2016	Geometry, Thermal Zone	Revit	Energy Plus
Calquin et al	2014	Geometry, T. Zone	Revit	DesignBuilder & Ecotect
Jalaei and Jrade	2014	Geometry, Space Type, T. Zone, HVAC	Revit	Ecotect

A Case Study

In this chapter, explanatory information about a sample energy analysis simulation study to be carried out in the future is given that Design Builder and Energy Plus programs will be used in the project.

Simulation Parameters of the Study

The following parameters will be used together with the relevant programs:

- Climatic parameters: various information about the outdoor environment such as temperature, relative humidity, wind speed are stored in the weather file of the Energy Plus program.
- Architectural parameters; main architectural parameters related to the building envelope; building shape, thermal permeability coefficients of building components, window transparency ratio, solar heat gain coefficient of transparent components, visible light transmission ratio of transparent components and solar reflectivity percentage of opaque components in Design Builder program.
- Electrical parameters; illumination power density is the most important parameter related to electricity defined in the program. It includes the total electrical power density and socket loads of the entire building. Unit is W/m^2.
- Mechanical parameters; it includes a natural gas etc. boiler heating system and radiators.
- Renewable energy resources design parameters; in the study, photovoltaic panel (PV) panel design parameters using the energy received from the sun and heat pump design parameters using the heat obtained from the soil are included.

Stages of The Study

In the study firstly, two-dimensional (2D) drawing of an existing building is prepared with the AutoCAD program according to the architectural projects and will be saved in DXF format.

Then, used the Design Builder input section, the building location template and building orientation information are entered into the program.

The outline created in 2D DXF format is then converted into DWG format, used three-dimensional (3D) design data format. In the model created in three dimensions (3D) in DWG format, all floors are defined with the add building command and all spaces on the floors are defined with the add partitions command, and the windows of the model whose floors and spaces are defined are defined into floors according to the architectural project and the floors are combined.

In the second stage, all systems that affect energy consumption are modeled separately. In this direction, firstly, the activity segment is entered and projection, computer, hand dryer, elevator, heated air curtain and so on. By entering the socket loads, the equipment load of the building in W/m^2 is defined. In addition, information on whether there is heating in the defined areas, average person density and working hours are recorded.

Insulation values, wall, roof and flooring information etc. Are defined according to the architectural projects of the building on the interface. The glass and joinery information according to the architectural project sections and the lighting intensity values according to the building electrical projects are entered into the program separately for each space in W/m^2.

According to building mechanical projects, heating, ventilation and air conditioning data (HVAC) are entered into the program separately for each location. If natural ventilation is used in the building, Natural Ventilation is activated.

As a result, the annual simulation results can be viewed in detail with the help of the simulation of the model whose data are defined. Various analysis outputs can also be obtained from the Design Builder interface with the help of the Energy Plus program.

Conclusions

Energy is a power that is offered to the service of both society and industry in quality and economical terms and a resource needed human life in order to increase the quality of community life, to increase the comfort level of people with decrease energy consume and to provide healthy environments. In this review, energy use also plays a key role for economic and social development.

Today, the issue of energy efficiency has gained great importance due to the decrease in energy resources and the harmful side effects of primary energy resources on the environment. In this direction, the energy used in binalrad should be used and planned in the most cost-effective way. In this respect, increasing of energy efficiency used in buildings is becoming increasingly common in the world. Countries constantly transfer technological developments to energy systems in order to reduce costs and reduce environmental damage such as global warming.

This article focuses on building energy modeling. In the study, BIM and BEM building modeling systems, Industry Base Classes (IFC) and Green Building XML (gbXML) data formats were examined, and it was determined that these formats constitute the basic standards.

Computer-aided Building Information Modeling (BIM) systems, developed for more efficient design and construction of buildings, have now been taken one step further and Building Energy Modeling (BEM) tools have been developed to examine building energy performance to improve building energy consumption. Building energy modeling can yield more reliable results to the building design process and better energy efficient results compared to calculations made by designers manually.

As a result, in this study, the importance of the Building of Information Modeling based Building Energy Modeling in the energy of efficient building design and improvement of existing buildings has been indicated the importance and proposed that the best known and most widely used BIM / BEM tools as Energy Plus, DOE-2, TRNSYS, Archibald, Revit, Archibald, Energy Plus, e-QUEST, IES-VE and Green Building Studio can be used for building energy simulation modeling.

Henceforth, Design Builder and Energy Plus programs will be used together in the building energy simulation project for future. Thus, the insulation values of the building envelope, glass shading coefficients, equipment efficiencies, lighting parameters, sensors, automation scenarios, building occupancy rates, alternative energy systems, roof material reflection coefficient, etc. By defining many parameters to the program, the model will be created and the annual energy cost of the building will be calculated.

Thanks to this, fast and less costly building energy models can be developed or the energy performance and energy consumption such as existing buildings energy simulation includes thermal of design analysis, cooling and heating loads, overs hadowing, energy consumption,lighting and daylight assessment,lifecycle costing, water usage, airflow can be examined.

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Research Paper

Modelling of Particle Matter Pollution in 2021 Autumn in Kosovo Region of Konya province, Turkey

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Abstract: Urban growth and energy consumption are directly related to air pollution; the growth in the number of vehicles and traffic on the avenues is the main cause of air deterioration. Energy consumption has a negative impact on the air, mainly in winter, where heaters are used more intensely. Likewise, air pollution can travel to places where there are no polluting sources. This global character has brought to the discussion the creation of global policies to combat pollution and find those who are responsible for its remediation. Particulate matter is part of the atmospheric pollutants and receives special attention due to its physical and chemical characteristics; they are liquid or solid, organic, or inorganic compounds that can have different shapes and be suspended in the air or not depending on their mass. From a medical point of view, particulate matter can cause health problems, primarily affecting the respiratory and circulatory systems. The objective of this study was to determine the level of pollution and distribution of particulate matter generated by vehicles and heating systems in the Selçuklu district of the city of Konya city. In the analysis PM concentration was performed at 11 temporary monitoring stations. Measurements were taken 5 times a day in 2 winter and summer periods of the year during the October month. The measurement data was modelled using Surf to generate maps of the distribution of particulate matter in the evaluation months. The results of the study show that the levels of particulate matter vary during the day. A high concentration is observed at 6 am and at 5 pm. Levels are reduced during that morning and afternoon interval. This phenomenon occurs due to the high circulation of vehicles. At a seasonal level, during the winter higher levels of concentration of particulate matter are recorded. The points with the highest level of concentration are in the east of the study area. In general, according to the air quality index, the air quality of the study area does not represent any risk to people's health. In the study it is recommended to carry out a scope to determine the nature of the PM pollution and their sources of origin.

Keywords: *Air quality, Surfer mapping, modelling, Particulate matter, health,*

Introduction

Industrialization, urbanization, population growth and accelerating energy consumption indirectly affect the level of atmospheric pollution. Air pollution: It can be defined as the deterioration of the chemical, physical or biological composition of the air we breathe. It occurs with the change of natural values when unwanted substances (pollutants) enter at levels that the environment cannot tolerate (Ezzati et al., 2004; Russell, 1974; Sarla, 2020). Air pollution is a phenomenon associated with the activities of today's societies. However, research shows that non-industrial agricultural activities contribute to air pollution in developing countries. Although the biggest source of pollution comes from human activities, another important source of pollution comes from natural ways. Volcano eruptions, decomposition of organic matter, transport of particulate matter with air currents, forest fires are some types of natural pollution (European Commission, 2010; Russell, 1974). This occurs in the lower atmosphere and is considered an environmental impact with a half-life of less than one day or more than one year. Affects locally, regionally, and globally at the geographical level; therefore, it is accepted as a public health problem and determinant of health (Buonanno & Hänninen, 2018; Seigneur, 2019).

Air pollutants are unwanted substances in solid, liquid, or gaseous form that are thought to cause illness in humans. Pollutant materials have several different physical or chemical properties changing on their ability to make toxic effects. Air pollutants can be emitted directly into the atmosphere or created in the atmosphere through chemical reactions (hydrolysis, oxidation or photochemical reactions) or physical (conversions from gas to particles). Accordingly, they are divided into two groups as primary

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and secondary (Rosenson et al., 1991; Seigneur, 2019; U.S. DHHS, 2021). The World Health Organization (WHO) has identified 6 main air pollutants harmful to health: PM, tropospheric ozone, sulphur dioxide, nitrogen dioxide, carbon monoxide and lead (Manisalidis *et al*., 2020). According to World Health Organisation attributed about 7 million people death to the impact of PM (outdoor and indoor) (WHO, 2014).

Particulate matter is an atmospheric pollutant of natural or anthropogenic origin, which can be in liquid or solid form, organic and inorganic, and of primary origin (combustion of fossil fuels) or secondary origin formed by reaction with other substances in air (Manisalidis *et al*., 2020; D'Amato et al., 2010; Yeşilyurt & Akcan, 2001). Particulate matter may diffuse directly into the atmosphere or may consist of precursors such as SOx, NOx, NH_3 and volatile compounds in the atmosphere (Kaya & Öztürk, 2013). Particulate matter does not have a specific chemical structure. They may consist of a mixture of organic and inorganic substances with variable physical and chemical composition due to their origin (Abulude, 2016; Daellenbach *et al*., 2020). Climate change and air pollution have environmental problems that make the same denominator with human activities. Climate change is the effect of air pollution produced by changing the composition and chemical concentration of gases in the atmosphere. However, these two problems affect the environment at different temporal and spatial scales. While air pollution is a problem that can manifest itself in a certain period and in a certain area, climate change is a global and long-term problem that affects all lifestyles in the worldwide (Manisalidis, *et al*., 2020).

Air pollution causes a decrease in air quality in the short term. Second, it is a concept related to human exposure to a polluted environment. Due to the growing concern about the health problems caused by air pollution, governments and non-governmental organizations have started to emphasize the need to improve air quality through public policies. Air quality is a concept that assumes that humans are the most important part of the environment and therefore the receiver of pollution (Ott, 1982). Similarly, air quality is assessed through indicators (air pollutants) whose half-life in the atmosphere is long enough (more than a week) to directly affect the receiver or be transported elsewhere (Akimoto, 2007; Griggs & Noguer, 2002).

The Air Quality Index (IQA) was prepared by the Environmental Protection Agency during 1971 (EPA, 2022). The index considers 5 pollutants: carbon monoxide, particulate matter (PM_{10}), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and tropospheric ozone (O_3). This index is a number representing the level of contamination based on the hazard level for human exposure. The index was developed to provide a decision-making tool for creating plans focused on reducing air pollution (Suman, 2019; Buonanno & Hänninen, 2018). IQA has succeeded in achieving some targets set by Environmental Protection Agencies and Ministries of Environment in some countries. These targets relate to limiting climate change; It reduces the risk of toxic pollutants and protects the ozone layer from degradation. Some studies show that although visible air pollution has decreased, there are still health risks due to low pollutant concentrations (invisible pollution). This is because indices such as IQA use high tolerance thresholds in the form of numerical values that categorize air pollution as good or bad (Domingo et al., 2021; European Commission, 2010; Suman, 2019). Some air quality studies have been conducted using databases of monitoring stations away from the exposure area. The reason for this is the economic difficulty of having monitoring stations at different points (Dursun & Aguilera, 2022; Ott, 1982).

Particulate matter (PM_{10} and $PM_{2.5}$) concentrations were monitored during autumn period, for determining the air pollution level in the Kosovo region of Konya city. The information was analysed through a standard pollutant indicator (Standard Contaminant Index). The obtained data were used in cartographic modelling to determine its distribution in the district and to evaluate people's exposure levels. The study was carried out using Kriging model method in Surfer programming to determine the air quality of Konya province. These analyses provide elaboration of scenarios for pollution distribution trends and source identification. The PM10 pollutant database of the monitoring stations determined for pollution analysis in Konya was used. The analysed information corresponds to the autumn months of 2021.

MATERIALS AND METHOD.

Research Area

The study area is in Konya, Selçuklu Municipality, Kosova District. The neighborhood has an area of 756.39 hectares. The location coordinates are X = 457944.68 and Y = 4202719.58 WGS 1984 UTM

Zone 36N (Fig. 1). The district is 12 kilometres away from Konya city center (Figure 1). Its average height above sea level is 1,016 m (Ministry of Environment & Urbanization, 2020). Kosovo District is bordered by Bosnia-Herzegovina region and Academy districts in the north in the east, Sancak District in the south, Beyhekim and Yazır Districts in the west and finally Büyükkayacık District in the east. According to the data of Selçuklu Municipality, approximately 31,900 people live in the Kosovo district (Selçuklu Municipality, 2016).

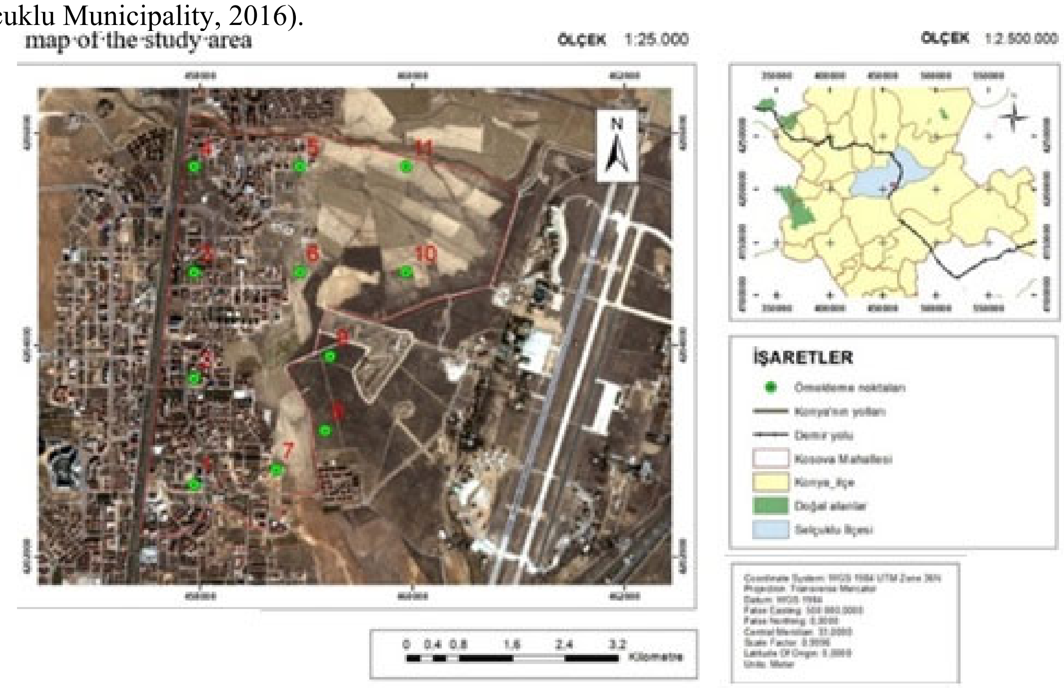


Figure 1 Location map of the study area including sapling points.

The research area has a continental climate with low precipitation levels ranging from 280 to 350 mm annually. The average daily temperature in the region is about 11ºC. The dominant wind direction is from north-northwest, and the annual wind speed is about 2 ms^{-1}. The research area is in a wide plateau surrounded by 2 high mountains ranges in the north and west (Ministry of Environment & Urbanization, 2020; Çiftçi *et al*., 2013; Topak & Acar, 2006).

Materials

Particle Counter PCE-PCO-1 equipment was used for the air quality measurement sampling. This equipment has a laser automatic particle counter feature, that enables the measuring of particle dimensions from 0.1 to 10 µm in size. The device has a sensor that measures the temperature, relative humidity, and dew point of the air. Using Surfer 11 software, the distribution from the pollutant sampling point was modelled using the Kriging spatial interpolation method and the distribution density map was created. This tool will be used in thematic cartography, such as detailing PM concentration maps at 11 sampling points in the Kosovo region.

Air Quality Measurement

Considering the dimension of this study area, were 11 temporary sampling points determined. The sampling stations were taken as homogeneous as possible and completely representing the settlements within the study area. In October 2021, PM 10 µm and 2.5 µm dimensions measurements were made to determine the air quality in 5-time intervals in 4 different days, as Thursday-Friday weekdays and Saturday-Sunday weekends at each of the sampling stations, including weekdays and weekends. Measurements times were performed at 06:00, 09:00, 12:00, 17:00 and 23:00 on the all-sampling days.

Methods Used in Data Modelling

Each data set was arranging with the measurements results made in the research area. Every dataset was subjected to an exploratory dimension and structural data analysis to evaluate and observe the behaviour of all data. This initial analysis allows to identify correlation, identify outliers, and analyse trends in data (Jumaah *et al*., 2019; Shukla *et al*., 2020). For the modelling was the Kriging spatial interpolation method used to model the concentration data of PM_{10} and $PM_{2,5}$. This method provides estimation of values from observed samples using weighted averages (Kumar et al., 2016). Equations of of method were given by [1 and 2].

$$Z^*(x) - m(x) = \sum_{i=1}^{n(u)} \lambda_i [Z(x_i) - m(x_i)] \qquad [1]$$

λi= are the weights assigned to the *Z (Xi)* data*; Z*(x)* is predictive*; Z(Xi)* is the value at the observation point*; XiM(x)* is the expected value or mean of the estimator*; m(Xi)* is the expected value or average of the observed data*; n* is the number of observations

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} \left(C_p - BP_{Lo}\right) + I_{Lo} \qquad [2]$$

C_p (average pollutant *P* concentration by standards); BP_{Hi} and BP_{Lo} are the upper and lower breakpoints of C_p, respectively; I_{Hi} and I_{Lo} = AQI values of BP_{Hi} and BP_{Lo}

Characterization of the Study Area

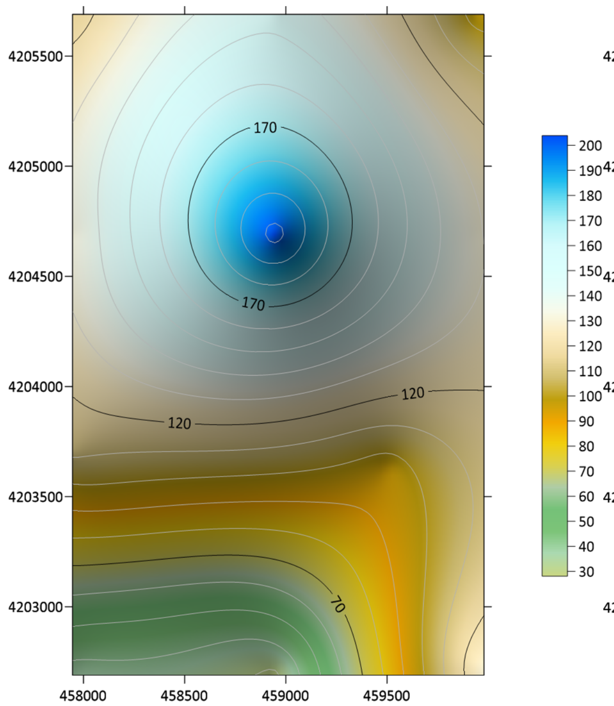
Soil particles on the surface exposure to the active wind can become suspended, increasing the particle matter levels in the ambient air (Buschiazzo *et al*., 1983). Since Konya has an arid-semi-arid climate ecosystem has limited agricultural development, it is inclined to wind erosion (Ministry of Environment & Urbanization, 2020). The eastern part of the study area is covered with an open area without vegetation extending to the airport (Figure 2). Much of the land is used for growing corn. However, there are areas where the land has been converted into construction. It shows that the green areas in the region show a high level of vegetation, but some areas are scattered and have low vitality. Much of the area has bare soil and dead vegetation. There is an industrial zone in the north-east of the region. Kosovo neighbourhood is developing rapidly, and constructions are continuing. Construction areas in the region are separated from plant areas and separated from areas covered with vegetation. Since the measurement point is around the settlements, the emissions of vehicles used in traffic along with fossil fuels used for heating increase during the rash hour periods.

Figure 2. Sampling points in the study area and the area used in the modelling.

Results

The following prediction maps were obtained by interpolating the particulate matter concentration variables (PM10 and PM2.5) with the Kriging method, considering data trends and their fit to the model with the global function. Figure 3 shows the distribution map of PM_{10}. 5 different hourly values from each point on Thursday-Friday were obtained by analysing the Periodic average value. In Figure 4, the average of PM_{10} values obtained from 11 measurement stations at 5 different time intervals on weekends (Saturday and Sunday) corresponds to the different sampling averages evaluated. It is seen that PM_{10} concentrations are separated by contour lines obtained from the modelling. While the highest values were observed in the central northern region of the weekday map (around the sampling point 6), lower concentrations were observed in the south/southwest part of the region. Weekend PM_{10} values are higher than during the week, reaching the highest value in the North-West corner compared to the central areas. The south bay is seen with a lower concentration like weekdays in the region. When the hours measured in October 2021 are examined, higher concentrations are observed during the hours when the activities increase, while lower concentrations are observed in some hours.

Figure 5 includes the map of $PM_{2.5}$ concentration distribution on weekdays in October. Figure 5 is the distribution modelling of $PM_{2.5}$ versus the result of the average of the measurements at 5 different sampling hours from Thursday to Friday. Like PM10 weekday values, the highest value is observed in the northern part of the study area (around sampling point 6). The densities decrease from south to east and the lowest value is in the southwestern part of the map, the densities show lower values towards the center and west of the map. PM10 was nearly 10 times higher when compared to weekday values. Figure 6 presents the modelling map of PM2.5 measurement values at 5 different sampling times from 11 measurement points on the weekend of October (Saturday-Sunday). It is seen that the highest concentration for $PM_{2.5}$ weekend values is in the south-west of the study area (around sampling point 9). The high value here is inconsistent with other measurement parameters and concentrations. $PM_{2.5}$ Weekend values were approximately 10 times higher than PM_{10} weekend values, just like weekday values. Weekend $PM_{2.5}$ concentrations are relatively higher than weekdays. In addition, values can be investigated that both $PM_{2.5}$ and PM_{10} pollution concentration maps have shown a real correlation in measured concentration record where both of PM_{10} and $PM_{2.5}$ values are high.



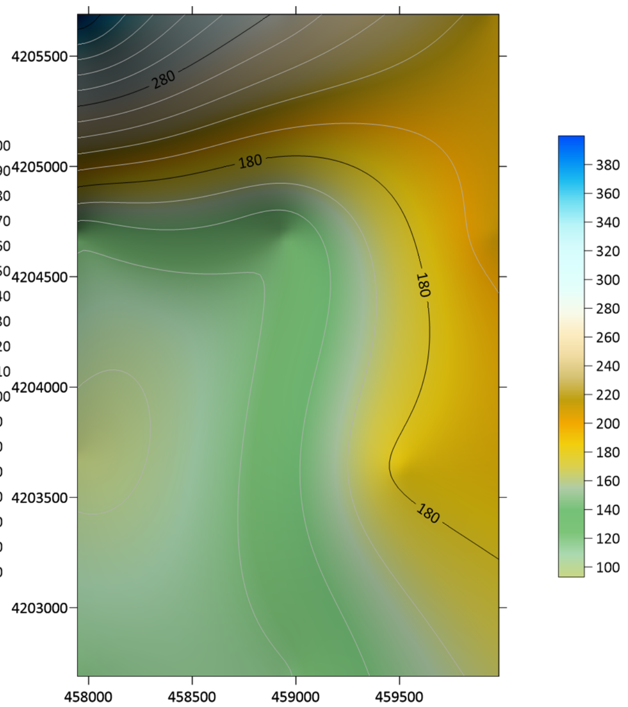


Figure 3 Map of PM10 concentrations weekday **Figure 4** Map of PM10 concentrations weekend

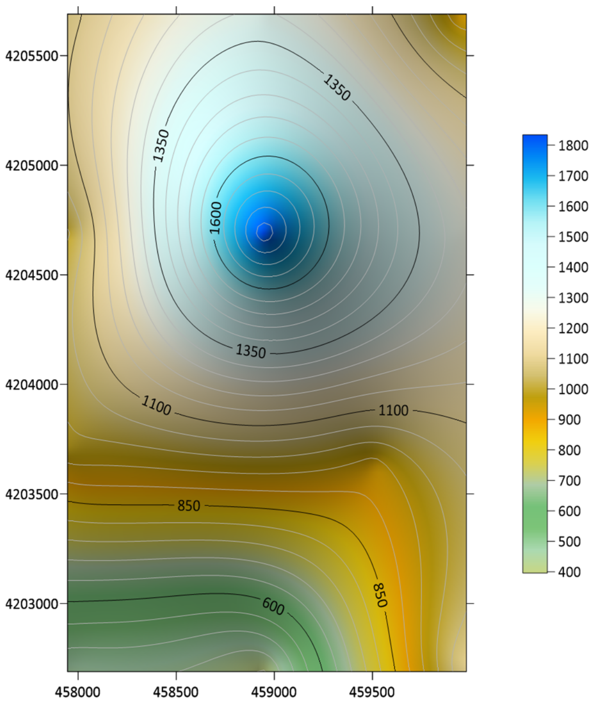


Figure 5. Map of PM2.5 concentrations weekday

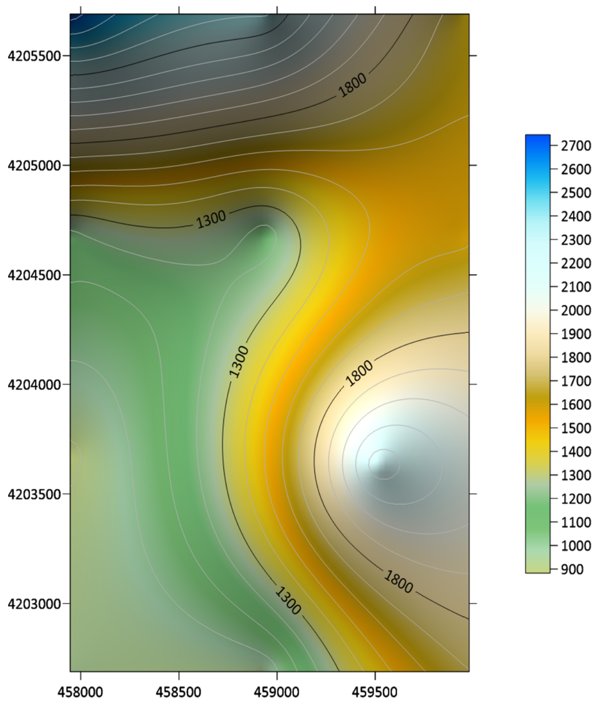


Figure 6. Map of PM2.5 concentrations weekend

Conclusion

Particulate matter concentrations for the Kosovo region of Konya city vary spatially and temporally. The temperature and wind speed effects affect the suspended particulate matter concentration in the ambient air. For the affecting air quality, another factor is new constructions, cultivated areas, wasteland, poor quality fuel using for the heating system in winter and the presence of vehicle traffic. Even if there is no change in emission sources and amounts, sometimes meteorological conditions cause regional pollution to peak. Figure 2 shows that the eastern part of the study area is characterized by unplanted soils as well as an area where new apartments and houses are built. The research area covered with poor vegetation, there is a park place, garden and having ornamental areas of the city affiliated to the Selçuklu Municipality.

The results from modelling current measurements confirmed that the research area where the bad air quality was measured the areas poor vegetation. Figures 3 and 5 have shown the research areas with the higher PM concentration. As the eastern part of the Kosovo region is in the process of urbanization and new home construction, this region saw the highest PM10 and PM2.5 values especially in October. Green areas show lower concentration levels, but this does not mean that the air quality in these areas is good enough. Similarly, PM concentrations increase further in winter, mainly due to weather conditions. The station with a high PM10 rating has high atmospheric pressures and low wind speed levels that prevent pollution from dispersing easily.

The air quality in the district of Selçuklu, Kosovo varies according to the hours during the day. Due to the denser vehicle traffic, PM concentration values were found to be higher in the morning hours and towards the evening hours. Even if the results obtained are not dangerous for human health, long-term interactions may have negative effects or may be effective on people with some respiratory problems. Better air quality values were obtained at noon, indicating that the activities in this region are less at these times. Air quality should be monitored seasonally in the research areas. Since it is observed that there is a significant inverse relationship between the air temperature and the PM concentrations between the seasons, the best air quality is obtained in the summer months. Autumn season medium category air quality has stability with a higher frequency. There is an increasing deterioration in air quality during the winter season. This variability is close to the standards in the light of important findings from a meaningful perspective. It can be said that the average air quality in the Kosovo region is of medium quality. It can be said that the current conditions will not pose any health risks. Daily average PM10 concentrations are close to the permissible limits. According to these results, only January 2022 concentration values were found in the allowable range, except for one day.

Suggestions

To reduce air pollution in areas where people breathe, it is necessary to have stations where air pollution measurements are made and to increase their number. Although it is expensive to have automatic measuring stations, in some regions it may be preferred to measure air pollutant concentrations with classical passive or active methods. Therefore, it should be supported by laboratory studies to determine the emission sources and types in more detail. In this study, it will be beneficial to consider the reasons that affect the $PM_{2.5}$ and PM_{10} concentration in the district of Selçuklu, the use of poor-quality fuel as an energy source, the exhaust emissions of the vehicles in traffic, the weather conditions, and the improvement of the vacant land areas in terms of vegetation. The existence of vacant land in the region has been determined. However, the pollution values originating from the industrial establishments close to the researched neighbourhood should also be considered. For this reason, it will be necessary to conduct chemical analyses to determine the PM composition. It is necessary to include researchers on the subject in the decision-making processes on air pollution. It is recommended that district municipalities, especially Konya metropolitan municipality, encourage their students to create databases and thesis projects on environment. The results obtained will provide knowledge for future studies.

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Research Paper

The Impact of COVID-19 on Water Consumption and Treatment Capacity in Tourism Area: Example of Bodrum

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Abstract: The COVID-19 pandemic has caused many countries to close their borders, and large numbers of people have begun to spend their holidays and vacation time within their own countries rather than traveling abroad. This study assesses the impact of the pandemic on water consumption and wastewater generation in a popular tourist Aegean city (Bodrum, Turkey) and its suburbia where many visitors moved in to live there for an unforeseen future. The effects of the COVID-19 pandemic on water consumption within the residential and commercial areas showed a significant decrease in water consumption in commercial areas (%23) and an increase in the residential areas (%15) during the pandemic period. The wastewater in residential areas had to be treated in many on-site wastewater treatment plants, apart from the central treatment plants which may pose a risk to the groundwater and surface water resources of the region. This shows that the treatment technologies and capacities of wastewater treatment plants need to be revised for situations such as unexpected pandemics.

Keywords *COVID-19, pandemic, water treatment, water quality, water consumption*

Introduction

Since the first reported case in December 2019, the SARS-CoV-2 virus has spread rapidly across the globe. As of August 17, 2021, more than 600 million people have reported COVID-19 positive, and about 6 million people have died (Dong *et al*. 2019). Similar to any other country, Turkey faced a severe transmission of the virus throughout its borders with more than 16 million cases and more than 100 thousand reported deaths (Republic of Turkey Ministry of Health, 2021). During the pandemic, many urban dwellers ended up moving to their summer vacation homes for extended times to avoid crowds and community spread of the virus. These summer homes are mostly located in suburbs of small towns where water and wastewater infrastructure are capable of population increase only in the recreational season. Although there have been signs of unexpected increases in water consumption and water treatment, detailed studies are needed on the impact of the pandemic on water consumption, treatment, and the factors affecting these changes (Lüdtke *et al*. 2021; Bandala *et al*. 2021; Lau *et al*. 2009; WHO 2015; Kalbusch *et al*. 2020).

Meeting safe water demand is challenging issue in rapidly growing urbanized areas where consumption exceeds sustainable utilization of resources, especially in regions where there is already an ongoing water scarcity. The fact that the COVID-19 has affected human behaviour in all areas of life due to its high contagiousness, restrictions to routine urban life had to be taken to minimize human mobility to prevent the spread of the virus. This "slowdown" of activities impacted people's behaviour towards their environment. For example, In China, it is reported that the people's need to immerse in green spaces increased during the pandemic period in China (Cheng *et al.* 2021). When the Covid-19 virus epidemic peaked in North American cities, wealthy urban dwellers living in high-density cities fled to holiday homes in quiet neighbourhoods with locals (Balçık *et al*. 2021). During the Covid-19 period, the distribution of population densities in cities began to change. The progressive course of the epidemic caused people to migrate from urban to less populated areas and increased the population in

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rural areas. Therefore, this temporary migration situation has caused individuals to acquire a second home in rural areas and has led to the reshaping of urban density and urban order (Kunzmann 2020; Bich-Ngoc & Teller 2020). In Turkey, Bodrum is one of the most popular touristic towns in the Aegean region, receiving of visitors from across the globe during summer months. During the pandemic, sudden and permanent population increase has been also observed in this region.

Since the beginning of the pandemic, researchers published hundreds of articles in 2020 focusing on the research and discussion of COVID-19 related to water research. Various webinars were also held to timely update research and exchange ideas on COVID-19 in the water and wastewater sector. Some of these studies are on the effects of human and industrial mobility in the regions on water and wastewater sectors during the epidemic (Stoler *et al*. 2020; Howard *et al*. 2020; Donde *et al*. 2021; Bin *et al*. 2021). The number of studies on the consumption and how human migration impacted water resources though have been limited.

The purpose of this article is to investigate whether the unprecedented level of population increase create a stress on the existing water resource management plans in the region. Specific objectives were: (i) evaluate how the COVID-19 pandemic affects urban water consumption and (ii) discuss the risks that can be observed in water treatment during the pandemic period in a city with many on-site wastewater treatment plants. To the authors' knowledge, this is the first study to evaluate one-year data of COVID-19 pandemic on water consumption and treatment in tourist destinations in this region.

Material and Methods

Almost a year into the pandemic, the Health Ministry of Turkey has been taking a series of measures to slow down the spread. Soon after the first case on March 11, 2020, the government activated an emergency response plan that evolved over time with a suite of precautionary activities, also impacting Bodrum (Fig. 1). The travel restrictions along with the timing of the year, many individuals who own a second house in the Bodrum region ended up deciding to stay instead of going back to their permanent residencies which are often located in metropolises such as Istanbul, Ankara, or Izmir.

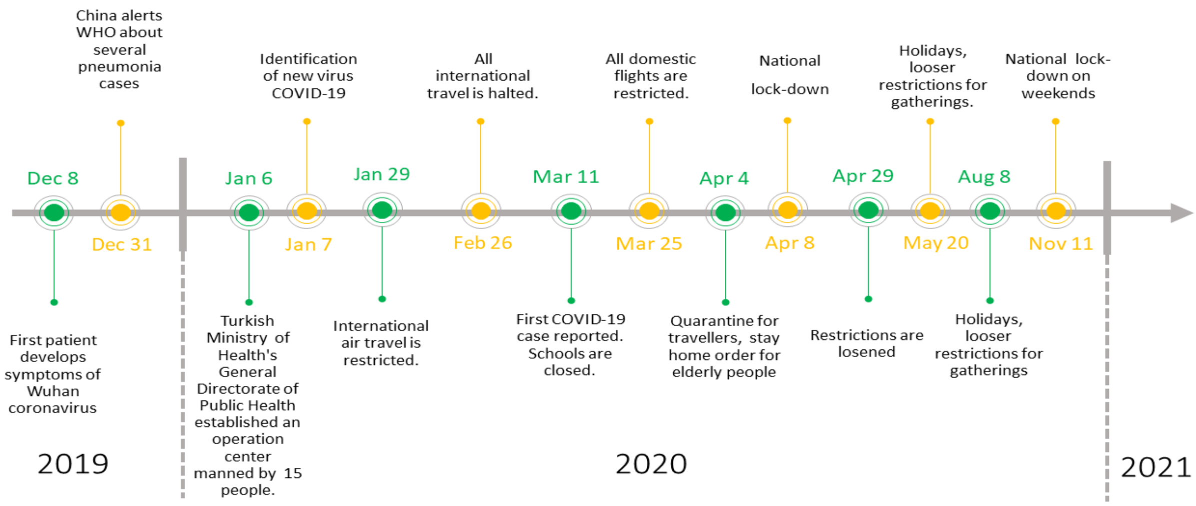

Figure 1. Timeline for COVID-19 related restrictions.

Bodrum, Turkey's most important and popular tourism region, is one of the thirteen districts of Muğla (Fig 2). Bodrum is a region that covers an area of 680 km^2 and the total coastline is 174 km (Koç *et al*. 2017). The most important settlements in the Bodrum Peninsula include Turgutreis, Ortakent (Yalıkavak), Türkbükü, and Karaova with this the center of Bodrum. The Bodrum, which is in the form of a peninsula, is located at the southwestern tip of Turkey and has both tourism and rich history due to its geographical location. The population of the Bodrum peninsula reported depends on official registered data of the Turkish Statistical Institute (TUİK) and is based on the population of off-season residents. In order to determine the tourism season population in Bodrum, it is essential to know the people who live in summer homes, tourist arrivals, and daily visitor population. However, these data are not officially available. As people started to migrate to the region during the pandemic in the off-season in 2019, water resource management planning has been difficult. Secondary data such as information on tourism facilities and bed capacities, the total number of residences, and occupancy rates during the year are available and can be a way to address these population shifts (Koç et al. 2017). In order to compare the water consumption of the previous period and the following period of COVID-19, the 2019 and 2020 water consumption data in Bodrum were taken from the Muğla Metropolitan Water and Sewerage Administration General Directorate (MUSKI) by separating commercial and residential areas. In addition, treated water data were obtained from the 12omestic wastewater biological treatment systems operated by the MUSKI for 2019 and 2020. The locations of the central wastewater treatment systems are given in Fig. 2.

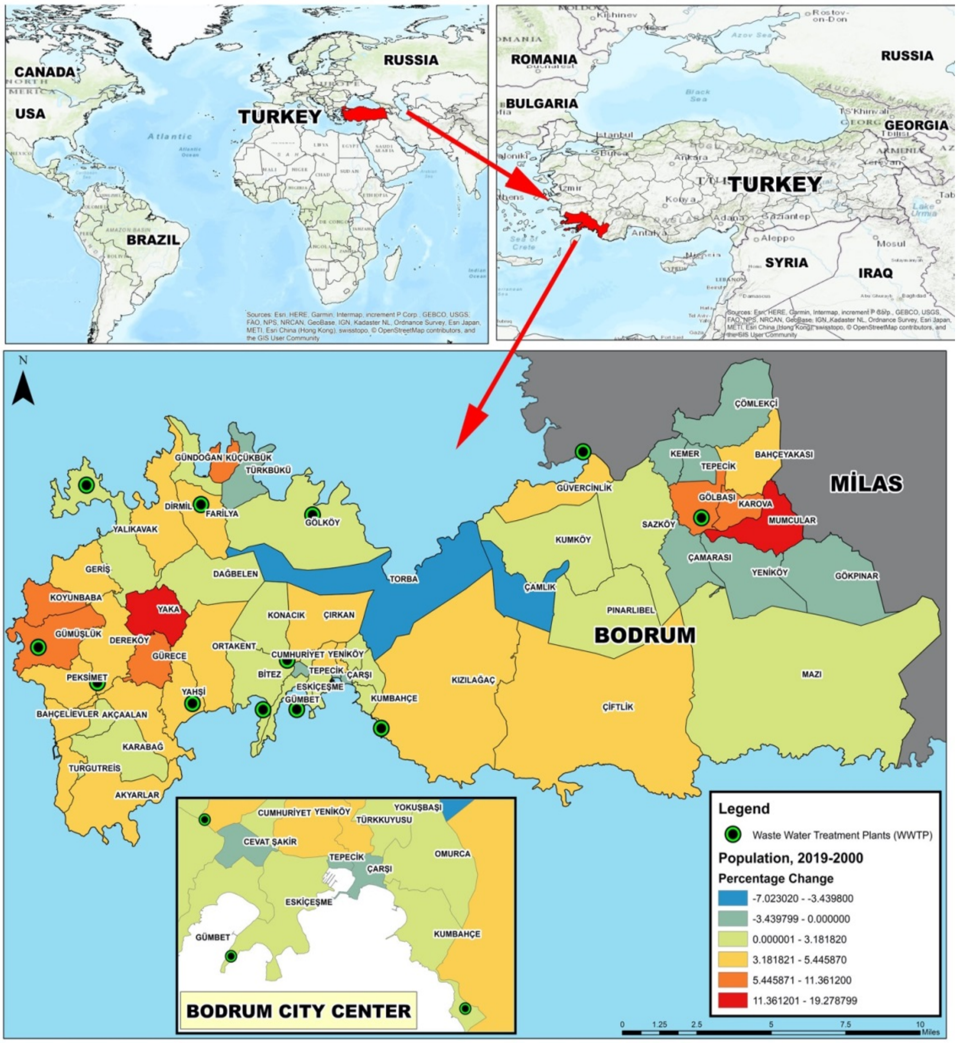

Figure 2. Neighbourhood population percentage change for 2019 -2010 in Bodrum

Statistical analysis

In this study, GIS techniques and classical statistical methods were used to produce a relation between population and water consumption value by considering wastewater treatment plants in Bodrum, Turkey. The provided consumption data are grouped on a neighbourhood basis and the annual consumption of both residential and commercial business subscribers is calculated based on the neighbourhoods. Water consumption data in the form of tables belonging to subscribers obtained from MUSKI was related to fifty-six neighbourhood areas of Bodrum District created in ESRI ArcGIS 10.3 application. The associated verbal data can be analysed in geographic information systems. Water consumption values of houses and workplaces in 2019 and 2020 are graphically mapped. In addition, correlation analysis was applied to assess the statistical associations between all data, and correlation coefficients were used to determine the positive and negative relationship between the two detected variables. The relationship between the number of passengers arriving in Bodrum from domestic and international routes and the water consumption values in Bodrum was examined.

Results and Discussion

Seasonal population change

One of the most significant impacts of the pandemic had been the decline in air travel, which significantly affected Bodrum as this had historically been the most preferred transportation for tourists. Before the pandemic, June, July, and August have traditionally been the high season. The number of international passengers in January 2019 was only 17, which reached over 200K in July 2019. This trend was significantly impacted by the pandemic. In 2019, the total number of domestic and international passengers coming to Bodrum was over 2 M, whereas this number decreased to less than 750K people during the pandemic. The airport activity data show a 59% decrease in domestic travellers and a 75% decrease in international travellers in 2020 (Fig. 4). Similarly, the number of domestic and international flights coming to inbound Bodrum decreased by 43% and 56% respectively during the pandemic (Fig. 3). Among 161 hotels that were open before the pandemic in Bodrum, only 46 stayed operational in 2020, demonstrating a 72% decrease in lodging activities. These were the only hotels that had permits with a safety certificate issued by the central government. The number of passengers arriving in Bodrum for 2019-2020 was obtained from the General Directorate of DHMI in Milas Bodrum Airport (Fig 4). The number of incoming and outgoing passengers with domestic and international flights increased until August 2019 and then dramatically decreased. However, it is observed that the decrease in the number of these flights increased exponentially in 2020 with the COVID-19 flight bans.

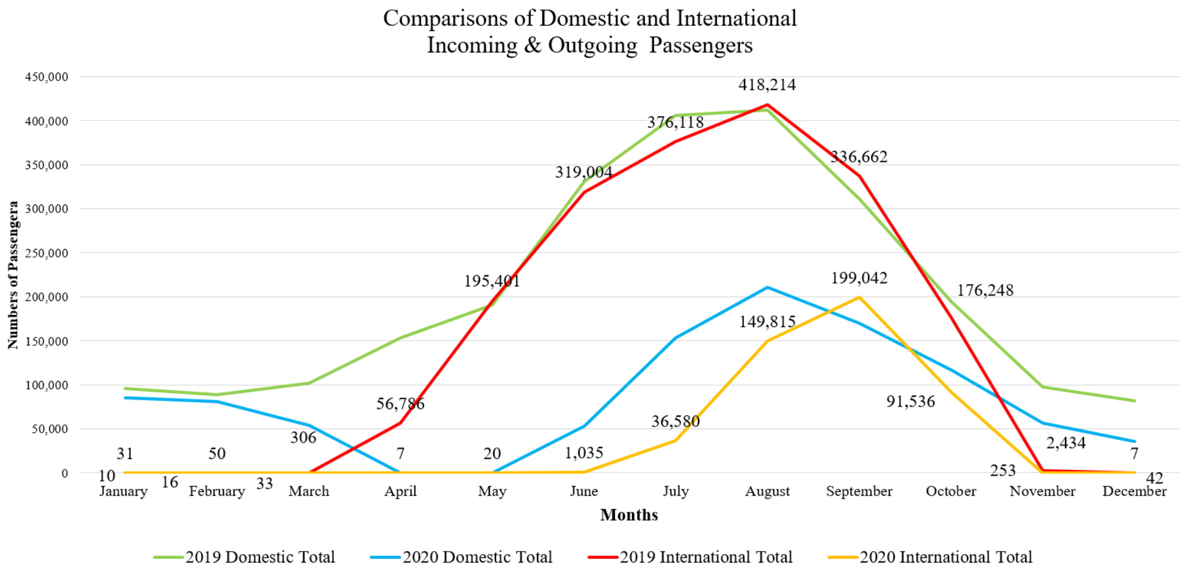

Figure 3. Domestic and international incoming and outgoing passengers pre and during pandemic

Water consumption

The amount of water used in residential and commercial buildings was compared in 2019 and 2020. Off-season winter months for these two years showed similar water consumption volumes in both residential and commercial buildings (Fig. 4). In the summer of 2019, the water consumption increased as expected during high touristic activity seasons. In the summer of 2020, however, during the pandemic, water consumption significantly decreased in commercial buildings. Residential water consumption on the other hand significantly increased in the summer months. This increasing trend continued in the last quarter of 2020, when the water consumption was twice of the previous year, the same period where it is usually known to be an off-season.

The significant relation between airfare ticket sales and water consumption before the pandemic (r^2=0.7981) decreased in 2020 (r^2=0.5578). Because the water consumption in residential areas increased, it can be concluded that people avoided already restricted air travel, some travelled by their cars for social distancing purposes and stayed longer periods of time in Bodrum, unlike they would return to their primary residential addresses.

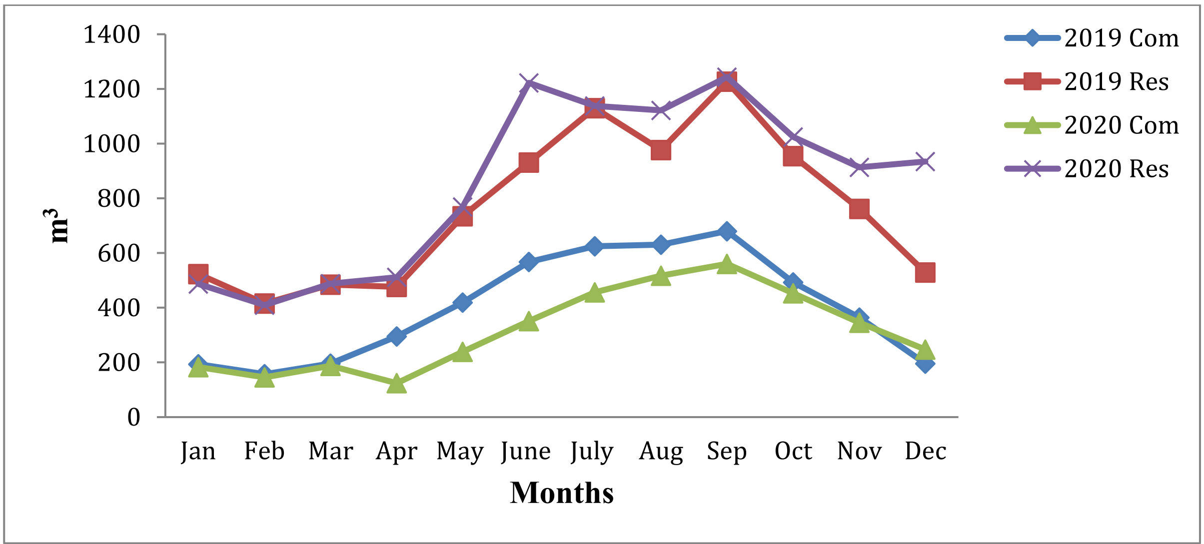

Fig 4. Water consumption of residential and commercial buildings between 2019 and 2020

Water scarcity is one of most the fundamental issues globally. Urban environments are particularly vulnerable to increased water demand due to high populations. Access to safe water becomes increasingly important during an infectious disease pandemic because handwashing is one of the primary prevention tools to reduce the spread in a particular region. In a pandemic environment, these challenges are exacerbated by enforced lockdowns where people had to stay at home for a long period of time. Our results show that increased water usage at the household level during these lockdown periods will create an additional burden on water resources, especially in regions with already have water scarcity conditions. It is clear that COVID-19 will likely be a part of our daily life in the unforeseen future, water demand will significantly increase in the future which requires additional planning for sustainable water resource management. Additional treatment efforts will be needed to bring "new water" to the planning which will also mean additional energy to be diverted to tackle this problem, which may also mean increased costs and pricing at the household level.

Kalbusch et al. (2020) analysed water consumption data of the Brazilian city of Joinville using various statistical methods, such as the Shapiro-Wilk test of normality (Ghasemi & Zahediasl 2012) and the non-parametric paired Wilcoxon test (Tian et al. 2019). The results revealed higher water consumption in residential buildings than in industrial and public buildings before and after quarantine periods. Such research studies closely monitoring different economic segments (*i.e.* high, middle, and low income) in urban settlements for possible changes in supply-demand patterns in the post-COVID-19 era will provide additional insights (Balamurugan et al. 2021). A comprehensive database for domestic and commercial water use can be leveraged with improved monitoring devices, various machine learning algorithms (Kasiviswanathan et al. 2016; Sun and Scanlon 2019), and empirical models (Balamurugan *et al*. 2021). Useful information can be provided to manage urban water needs.

Water treatment

There are twelve central wastewater treatment plants (WWTPs) in Bodrum (Fig 2). The volume of wastewater treated in these WWTPs increased starting in August 2020, where the general trend had been decreasing before the pandemic, showing that summer residents who can afford to stay, remained in these homes and did not return to their permanent residencies in other major metropolitan areas to avoid the pandemic. The volume of treated wastewater has been lower than the volume of water consumed in both years (Fig. 5). Similarly, there was no significant relation between airplane ticket sales and wastewater treatment (r^2=0.0053). This is because the central WWTPs serve commercial settings rather than residential areas, as these buildings are located away from the city center and wastewater treatment depends on 290 on-site wastewater treatment systems. While 74 percent of the 290 on-site wastewater treatment units are in residential sites, the remaining 26% are in tourism establishments such as hotels, motels, and holiday sites (CSB 2021). Unfortunately, there is no data available for these private systems to see the actual treated wastewater quantity across Bodrum.

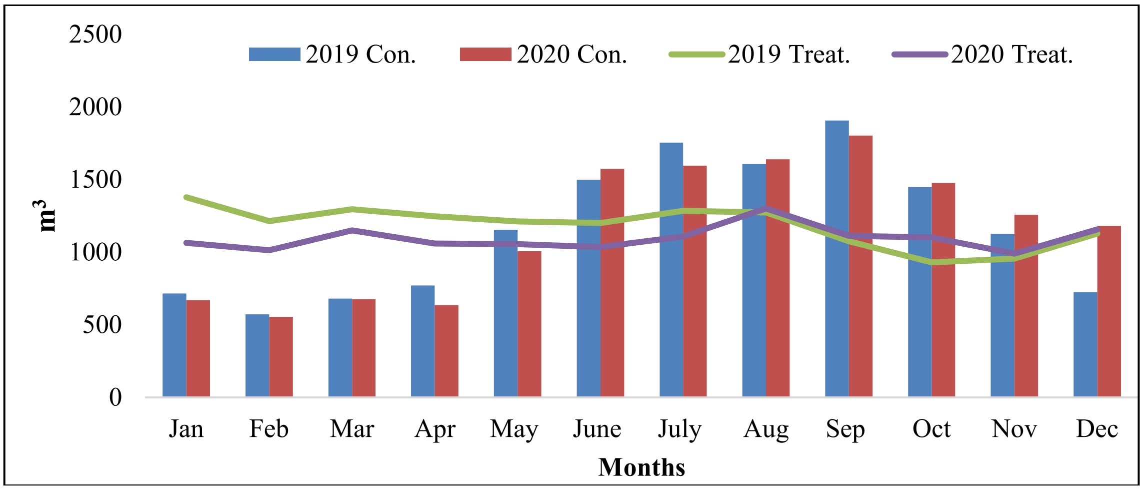

Figure 5. Total water consumption and treatment between 2019 and 2020.

There was a slight increase in the relation between airplane ticket sales and wastewater treatment in 2020, showing that even though the flights were very limited, there was some travel occurring during a pandemic, mainly due to business purposes. In fact, the relationship between the number of passengers arriving by airline and the amount of water consumed in commercial areas in Bodrum in 2020 was also significant (r^2=0.7392). In the post-COVID-19 periods, apart from the water demand and supply issues, the policies on wastewater treatment will change significantly. Since the wastewater flow values used in the planning and design of wastewater treatment plants are not constant or uniform, hourly, daily, monthly and annual changes show. In the design of the wastewater treatment plant, besides the wastewater flow rate, the current situation and future change must also be predicted.

The difference between the amount of water consumed and water treated in twelve central wastewater treatment plants (WWTPs) in Bodrum for 2019 and 2020 is given in Fig 6. The stark difference between water consumption and wastewater treatment shows a potential of 15-40% on-site treatment rather than treatment in WWTPs, particularly during the summer (Fig. 7). Interestingly, a similar trend was observed in December 2020 as well, addressing that people who arrived at Bodrum during the pandemic stayed in their summer homes throughout the winter as well.

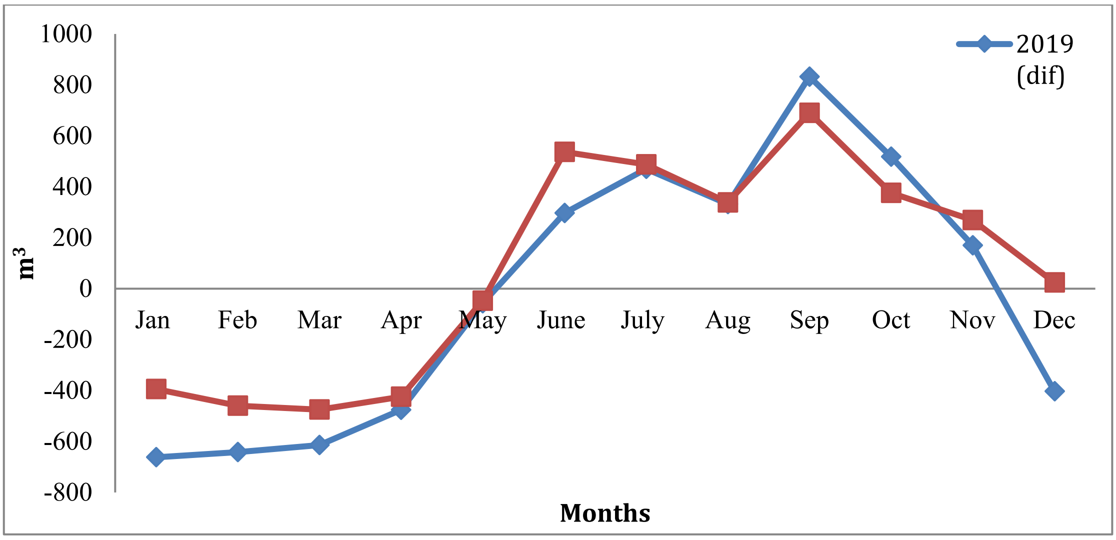

Figure 6. The difference amount of water consumed and water treated in Bodrum.

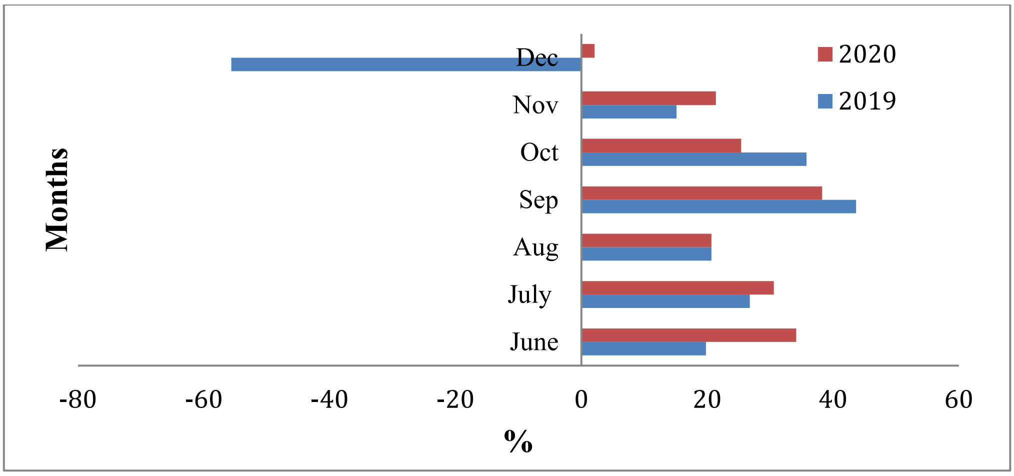

Figure 7. Percent change of water treated in on-site treatment plants in Bodrum by months.

Even though the water discharged after being treated and discharged from a large number of on-site treatment plants is used for irrigation of green areas, the excess of on-site wastewater treatment units, which are still far from control, is expected to pose a risk in the pollution of surface, underground and sea water in Bodrum. Perhaps this may be one of the causes of the mucilage-like pollution seen in the summer of 2021 in this region. Moreover, wastewater treatment plants cannot efficiently remove dexamethasone, favipiravir, hydroxychloroquine, oseltamivir, remdesivir, ribavirin drugs used in the treatment of COVID-19 and their metabolites in raw water (removal efficiency <20%). In toxicology studies, it has been determined that the main compounds of Chloroquine, hydroxychloroquine, remdesivir, ribavirin, and ritonavir or their metabolites pose a moderate ecotoxicological risk (RQ > 0.1) in the rivers (Kuroda *et al*. 2021; Eric *et al*. 2021).

In this context, as in the example of Bodrum, the determination of capacity to be determined for the treatment of wastewater in regions with very different summer and winter populations according to the period when the population is the most crowded will prevent environmental problems that may arise from the inability to dispose of wastewater originating from low capacity. It is thought that the basic technical methods and practices to be used for the selection of technology, design criteria, disinfection and reuse of treated wastewater, and the disposal of sludge generated during deep sea discharge and treatment activities of wastewater treatment plants related to the treatment of wastewater originating from settlements should be rearranged.

The lack of detailed quantitative analysis and detailed data on the water and wastewater sectors can always pose a problem for the Region. The questions given below can be considered to be issues that all countries can be addressed.

(i) How did the water use and treatment systems change in urban areas due to the changing population density and different industrial/commercial activities in the cities during the pandemic period?

(ii) What was the resilience of municipalities in coping with the sudden change in water demand and wastewater treatment systems during the quarantine?

(iii) Which cities experienced a supply-demand gap during quarantine and water supply problems during peak summer months?

(iv) Have new norms been set for water consumption and treatment after the pandemic?

Conclusion

The pandemic has given important lessons from sustainable water consumption and treatment perspective in touristic areas such as Bodrum. In touristic areas where hotel tourism is not completely dominant, and the number of detached summer houses is high, significant population pressure has occurred during the pandemic period. In these regions, which have a high population density only during the summer holidays, a serious population density had been experienced in the winter. For this reason, much more domestic wastewater was generated in summer houses. For a functional wastewater treatment plant to operate, it is critical to predicting the amount of wastewater and wastewater characteristics in the most realistic way. It is difficult to determine the daily and monthly population exchange rates in well-known touristic areas such as Bodrum, but results show that the capacity of wastewater treatment plants was not sufficient to address unexpected and increasing populations during the off-season. In this context, it is necessary to collect data or have access to predictive models to be prepared for any sudden event, such as the unexpected COVID-19 pandemic. Such drastic and rapid change in population will require additional preparedness plans that would involve bringing alternative water resources, cost-effective water treatment, increased capacity to store and treat additional water, and not least, efficient wastewater treatment (including plans for reuse). In addition, it should be considered that with the increasing migration to regions such as Bodrum, which are intertwined with rural tourism, increases in water use and the amount of wastewater generated, and serious changes in the biological and chemical character of the wastewater.

To solve water treatment issues, it will not be enough to reduce the number of on-site treatment systems and establish conventional central wastewater treatment plants. The ecotoxicological impact of effluents should be determined before additional investments are made. Such planning needs to be made sooner than later. The pandemic situation should be recognized as a key, and capacity needs to be developed in the water sector in terms of infrastructure, wastewater treatment procedures, water, and wastewater monitoring and management of the water sector.

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