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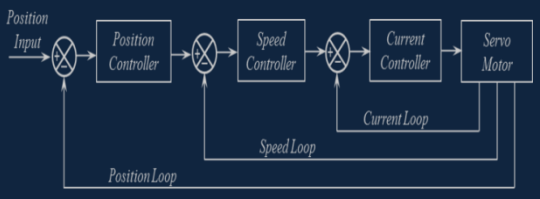

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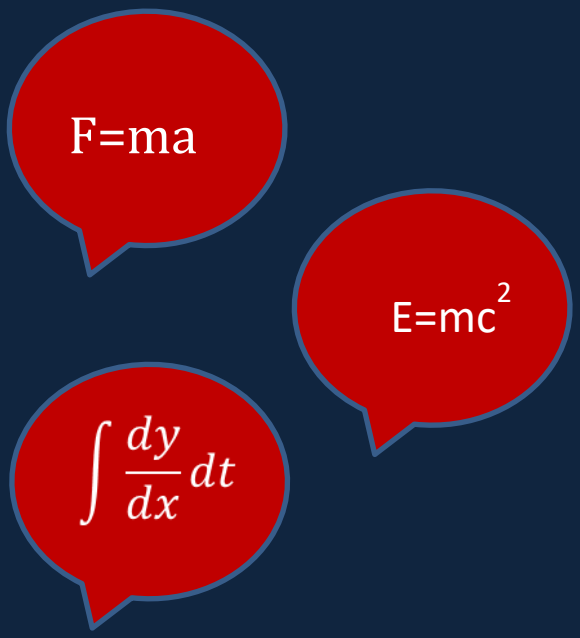

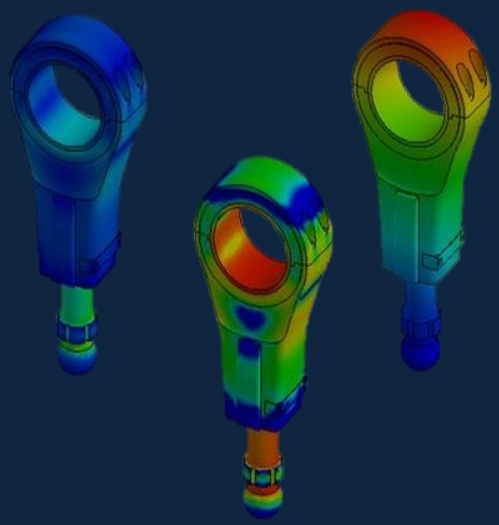

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Research Article

Investigating the causes of delay and cost-overrun in construction industry

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ABSTRACT

For a construction project to be successfully completed, project objectives must be met within a specified time and budget. 'Delay' and 'cost-overrun' in the construction projects are two significant defects, as they can negatively affect projects by disputes among stakeholders, work quality and safety level in the project. Hence, it is crucial to have further investigation on these especially in regions where less considered. To overcome such problems and inconsistencies in the construction industry of Northern Iraq, major factors and causes of delay and cost overrun were investigated in a considerable number of construction companies in the region. Sixty-one delay factors and forty-two cost overrun factors were considered in the study. A questionnaire survey was administered, and a quantitative analysis was conducted by SPSS. Major delay and cost overrun factors were determined and the three major causes of delays were found as "security measures", "high number of sub-contracts by the same contractor", and "poor labor productivity". Similarly, three major factors causing cost-overrun were "inadequate labor and skill availability", "inappropriate contractor policies", and "domination of construction industry by foreign firm and aids". It was also found that the majority of problems are raised by owners and contractors. An improvement framework was finally proposed based on findings.

1. Introduction

There is a vast need for more capable, timely and cost-effective completion of projects in the construction industry. There are inevitable and unexpected changes as well as problems occurring because of the design during the construction stages of projects, thereby causing delay and cost-overrun in projects.

Delay can be defined as an act of carrying out a task that could either be slower than anticipated or achieving a job which was initially planned to be done earlier. In the construction industry, delay in any form has lots of impacts and consequences which may cause obvious or hidden risks [1].

Construction process is characterized by inter-connected phases such that a delay in any of the tasks in a phase may cause serious problems to one or more subsequent tasks and involved parties, which in turn creates certain challenges to owner and contractor. Abandonment of projects is another effect of construction delays, which leads all or some of the construction project stakeholders abandoning the project entirely [2].

Many studies have been conducted to get intelligible understanding about the most effective factors of delay in Iraq construction industry. Jahanger [3] performed a study on the construction projects delay at city of Baghdad. Fifty-eight factors of delay were employed in his study. The study demonstrated that the most important causes of delay for construction projects are mistakes or unclearness in design documents, missing the planning and scheduling of project by the contractor, weak management and supervision of the site by contractor, unqualified contractors' technical staff, and in-accurate details in the working drawings. In another study on delay in Iraq construction industry, sixty-five factors were investigated by Bakr [4] and new chronological shape for the factors was concluded. According to the investigation and analysis results, the main factors were found to be inadequate early planning of the project, owners' lack of experience in construction, delay in hand-over the site by owner to the contractor,

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late payments by the owner to contractor, and deficiency in decision making by the owner.

According to some studies, cost-overrun is the difference between the final cost and the estimated cost of the project [5]. However, some others believe that cost-overrun should be found by comparing the initial amount of original contract value with the final cost when the project is completed [6].

Estimated costs are characterized as planned or measured costs which are prior to the inception of the construction project, regardless of the fact that the activity planning and scheduling process alters with project type, time and region. Actual cost is characterized as accounted cost decided at the time of finishing a task. It can likewise be said that cost-overrun is the sum by which real expenses exceed the standard or planned costs. Thus, cost-overrun is characterized as the difference and always positive. Some studies referred that cost-overruns are common in the projects [7].

Al-Agele and Al-Hassan [8] conducted a research on construction projects' cost-overrun in Iraq to identify the major reasons of cost deviation. Twenty-six factors were studied in their research. The study showed that the most important factors impacting cost-overrun are inability of company to meet project requirements, accepting lowest offers, inadequate planning, inaccurate estimation of the cost, and lack of control to the time of the project or predict the date of its end. In another research about the risks on the project cost-overrun, Jaber [9] demonstrated factors based on their impacts. The factors were security measures incurred due to corruption and bribery, governmental routines for late approvals, un-official holidays, loss incurred due to political changes, and increase in materials price.

Therefore, finding the causes of these delays and cost-overruns can be of major success factors for the contractors in construction industry. In this study, delay and cost-overrun and their causes will be studied in Northern Iraq with especial focus on construction industry.

2. Methodology

To investigate the causes of delay and cost-overrun in construction industry of Northern Iraq, a comprehensive literature review was carried out. Through analyzing the previous literature, the information about the causes of construction delays and cost-overrun and their effects on construction projects were used to design a questionnaire to collect data from the targeted respondents.

The quantitative method was carried out by use of a questionnaire survey. A questionnaire was designed according to the objectives of the study, which are causes of construction delay and cost-overrun. 'Close-ended question' method was also used in designing the questionnaire. The questionnaire was designed in 3 parts. The first part contains a covering letter together with general questions regarding the participant and the company, where second and third parts include questions relating to the causes of delays and cost-overrun and the responsible party causing the defect. Respondents were several parties involved in the construction process such as contractors, designers, owners, material suppliers, consultants, etc. Hence, the questionnaires were distributed across some companies in Iraq, and were duly completed by the staff members of the companies. The companies were basically construction companies.

The target population in this study was one hundred and twenty employees in ten well-known construction companies in the Northern part of Iraq. The questionnaires were distributed and duly completed by the participants. The companies were construction companies, which are professionals in different fields of construction industry. Out of the distributed questionnaires, hundred were returned which equals a rate of 83%.

The analysis of the obtained data from the questionnaires were performed using the SPSS software (Statistical Package for the Social Science). The results were converted into descriptive results that were useful for drawing an achievable conclusion.

3. Data Analysis, Results, and Discussions

Sixty-one delay factors were asked to be graded based on their importance and effect on projects. These factors were extracted from relevant literature and local and regional factors based on authors' experiences. The considered factors were the following: Security measures, high number of jobs by the same contractor, poor labor productivity, design errors and discrepancies in contract documents, poor controlling of subcontractors by the contractor, material quality problems, uncooperative owner with the contractor or the consultant, inadequate qualification of the consultant to the project, inadequate early planning of the project, deficiency in drawings, slow decision making process by the owner, delay in delivering the site to the contractor, absence of consultant's site staff, delay in approval of shop drawings, delay of material supply, weather conditions effect on construction activities, shortage of qualified engineers, delay in the preparation of contractor document submissions, delay in site mobilization, delay in giving instructions, unforeseen site conditions and geological factors, rise in the prices of materials, delays due to sub-contractor work, difficulties in obtaining work permits from the authorities concerned, documents not issued on time, changes in the scope of the project, delay in test samples of materials, shortage in equipment availability, technical problems in project site by the contractor, lack of high-technology mechanical equipment, unclear and inadequate details in design, late procurement of materials, government tendering system, breach or modification of contract by the owner, slow preparation of change order requests by the contractor, poor planning and scheduling of the project by the contractor, poor site management and supervision by the

contractor, lack of coordination with contractors, delay in the approval of contractor submittals to the owner, contract duration to construction of project is too short, improper construction methods implemented by the contractor, mistakes in soil investigation, weather conditions effect on construction activities, poor qualification of supervision staff of the consultant engineer, delay in progress payments by the owner, design errors made by designers due to unfamiliarity with local conditions and environment, the conflict between contractor, owner and consultant, economic conditions-local or global, poor qualification of supervision staff of the owner's engineer, delays in resolving contractual issues, shortage of construction material, official and non-official holidays, cash flow problems faced by the contractor, insufficient available utilities on site, poor qualification, skills and experience of the contractor's technical staff, equipment availability and failure, government change of regulations and bureaucracy, problems with local community, design changes by the owner, owners' lack of experience in construction, design changes by the consultant.

The 5-scale Likert grading was considered. Respondents were also asked to specify the party and elements responsible in each factor. The involved party could be selected among the project owner, contractor, consultant, designer, labors, external, materials and equipment. The results analysis demonstrated that the first responsible party is external elements, then owner in the second stage, and contractor as a third responsible party (Figure 1). External factors affect the construction project through different ways and used to evaluate through economic issue, social issue, political issue, physical environment, industrial relation environment, and level of technology. Since Iraq is politically, socially, and economically unstable country, previous and existing political conflicts led the external elements to have highest impact on the construction projects in Northern Iraq.

Moreover, these causes cannot be pinpointed to just one person or part of a construction team. Weather conditions, fluctuation of currency, increase in price of materials as well as many other external factors would be detrimental to the project, and collectively they will make a very high impact on the time factor of the project.

The owners were seen to be the second major party responsible for delays. This could be due to the major role of owners in any construction project. The cash flow, employments, equipment type, and other factors all fall under the decisions taken by the owners of the project.

The awareness of the owner about the construction legislation, predicted planning from owner side with accurate financial budget, and cooperation between the owner and other parties (designer, consultant, and contractor) will reduce the delay in the construction projects.

The third party with a high level of responsibility is the contractor, since it is his responsibility to manage the execution of the project and make sure all odds are met to guide the project through success. The main suggestions to the contractor to improve his ability to reduce the delay in construction projects can be enumerates by;

a) The pre-financial planning and estimation to evaluate the actual budget of the project, with good financial coordination.

b) Improve the management in the site to overcome any technical and even non-technical problem could take place in the site. This could be implemented through expert project manager, and good staff.

c) Good cooperation with other parties especially, owner, consultant, and supplier in order to coordinate whole the work and implement it in the time.

The returned questionnaires were then analyzed, and the factors were prioritized. Ten most important factors are presented in Table 1.

The suggested solution to reduce the delay in construction projects are to provide an especial security team by government, project owner or contractor to guarantee the security in the site which could add some extra cost to the project final cost; strict application of the rules or a legislation suggested to control the limits of binding, and how many contracts or project a contractor can handle at a time, as per his classification; the wages of workers also discussed to be negotiated and reviewed properly as well as other motivations in order to reduce the effect of poor labor productivity on the delay in the projects. Also, special training, workshops and programs seem to be effective, and will increase the knowledge and efficiency of the workers to reduce the impact on delay.

Figure 1. Responsible parties and elements causing delay

Respondents were asked to grade forty-two cost-overrun factors based on their importance and effect on projects. The factors considered for the survey were: Fluctuation in prices of raw materials, unstable cost of manufactured materials, fraudulent practices, kickbacks, corruption, mode of financing and payment for completed work, high cost of machineries, improper planning, high interest rates charged by bankers on loans received by contractors, frequent design changes, long period between design and time of bidding/tendering, lack of coordination between design team and general contractor, lack of cooperation between general contractor and subcontractors, high machineries maintenance costs, bureaucracy in bidding/ tendering method, lowest bidding

procurement method, litigation, numerous construction activities going on at the same time, scope changes occasioned by inadequate pre-contract study, scope changes arising from redesign, inadequate site investigation, inadequate preconstruction study, changes in owner's brief, work suspensions owing to conflicts, inadequate quality/ ambiguity of contract documents, inappropriate contractor policies, poor project (site) management/ poor cost control, control of construction industry by foreign firms and aids, contract management, inadequate duration of contract period, inappropriate government policies, inadequate production of raw materials in the country, poor financial control on site, absence of construction cost data, inappropriate contractual procedure, wrong method of cost estimation, inaccurate cost estimation, poor relationship between management and labor, stealing and waste on site, inadequate labor/ skill availability, disputes on site, adverse effect of weather, high cost of skilled labor, high transportation cost.

Table 1. Ranking of delay factors

Delay Factor	RII	Rank
Security measures	0.6420	1
High number of contracts by the same contractor	0.6400	2
Poor labor productivity	0.6320	3
Design errors and discrepancies in contract documents	0.5800	4
Poor controlling of subcontractors by the contractor	0.5660	5
Material quality problems	0.5620	6
Uncooperative owner with the contractor or the consultant	0.5610	7
Inadequate qualification of the consultant to the project	0.5590	8
Inadequate early planning of the project	0.5580	9
Deficiency in drawings	0.5570	10

Grading was considered like delay factors. The responsible party for each factor was also asked. The most responsible party was found to be the owner followed by the contractor (Figure 2). The owners control the financial part of the project, they know how much they can afford, when can raise the funds, and when these funds are not available; thus, where the project would have to be delayed due to instability in the budget. On the other hand, the owners sometimes might come up with new ideas required to be implemented in the project which imposes some additional cost. The clear idea for the owner about the project and good planning from owner side to implement the project, as well as good cooperation between the owner and other parties will avoid the cost-overrun in construction projects.

The second most important responsible party in this category is the contractor, since he is the second man in the project and the implementer of the ideas of the owner. The contractor is responsible because he is the manager of the money that is put into the project by the owner. Incompetency in management on the part of the contractor would lead to the problem of cost overrun. The suggestions to avoid the contractor impact on cost-overrun is through selecting expert contractors to implement the construction project, through qualifying the financial ability, technical ability, as well as legal condition of the contractor. The cooperation between the contractor and other parties in the construction project is another suggestion to overcome the cost-overrun in any project.

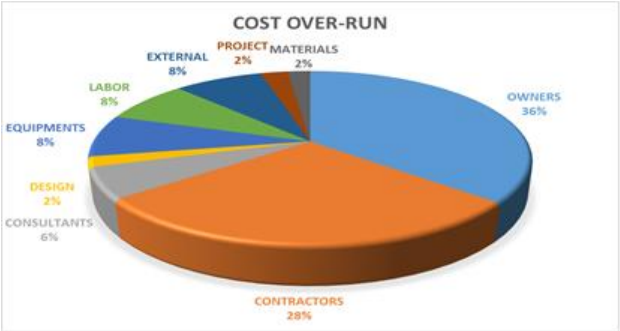

Figure 2. Responsible parties for causes of cost-overrun

Table 2. Ranking of cost overrun factors

Delay Factor	RII	Rank
Inadequate labor/skill availability	0.7760	1
Inappropriate contractor policies	0.6440	2
Domination of construction industry by foreign firms and aids	0.6380	3
Poor project (site) management/ Poor cost control	0.6300	4
Lack of coordination between general contractor and subcontractors	0.5840	5
High machineries maintenance costs	0.5700	6
Litigation	0.5350	7
Scope changes occasioned by inadequate pre-contract study	0.5340	8
Numerous construction activities going on at the same time	0.5320	9
High cost of machineries	0.5270	10

The questionnaires were then analyzed, and the cost-overrun factors were prioritized, and ten most important factors are listed in Table 2. To decrease the impact of the major cost-overrun factors, the owners should investigate the local skills thoroughly before bringing foreigner experiences. Attending different training courses, and improving the quality of education especially in this field will be assisting as well. Encouraging the contractors to be updated with new procedures and techniques through training courses can also decrease the cost-overrun impacts. Locally owned construction companies can be

involved more in projects and be motivated by long period low interest loans for machinery, and provision of facilities to export some types of machinery or materials with less taxes or (tax free) to help the contractor to achieve the work with lowest cost.

4. Conclusions

Delay in construction projects represents an important problem in Iraq as one of growing countries, because it will affect the strategic planning for the development of the country. Hence, time and cost related issues in the Iraq construction industry are issues that must be handled with uttermost caution and care. Thus, carrying out a research in this area will have a paramount importance. The analysis carried out in this study has proven that there is dialect between delay and cost-overrun. For example, when project costs are investigated and completely monitored, with keeping other factors constant, and only project periods increase, there will always be a proportionate increase in the construction project costs, and vice versa. Basically, the main objective of this study was to identify the major causes of delays and cost-overrun in the construction industry of Northern Iraq. These objectives were achieved through a questionnaire survey. Most important factors causing delay in construction projects were found to be security measures, high number of contracts by the same contractor, and poor labor productivity. On the other hand, most important cost-overrun related factors were found to be inadequate labor/skill availability, inappropriate contractor policies, and domination of construction industry by foreign firms and aids. To overcome the delay and cost-overrun problems, some recommendations were made such as provision of especial security teams, strict application of the rules, consideration of motivations for labors to increase their productivity, special trainings and workshops, more investigation on local skills, updating the contractors with new procedures and techniques, and motivation of locally owned construction companies.

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Research Article

Examining the risk of flotation in structures

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ABSTRACT

Lately, an increase in the number of floors in structures that have been built on valuable land can be noticed. While building these structures, a retaining wall is created, which is necessary for a safe foundation, yet this also causes the formation of a closed pool-like area. If the excavation site during construction is filled with water due to various reasons, basement floors, which form closed volume, may move upwards. The same problem may also be experienced in all elements that are underground in flood susceptible areas. Unfortunately, engineers often overlook this potential problem while focusing on the completed structure weight. This flotation damage should not be confused with liquefaction of ground that occurs as a result of unexpected movements in the structure due to the loss of the bearing capacity of the ground. The necessary calculations to avoid this risk are only conditioned for port and coastal structures in national standards and codes. Hence, this study aims to demonstrate the conditions leading to flotation in structures and necessary precautions to avoid them.

1. Introduction

Engineers generally consider structure load on the vertical plane along with earthquake and wind forces on the horizontal plane in order to design a safe building effectively. In addition, since the 1995 Kobe earthquake, earthquake engineers have to focus on the vertical force on the structure resulting from an earthquake [1]. Another factor that requires the attention of engineers to the vertical force on a structure is a tsunami [2, 3]. The tsunamis which happened in Peru in 1996; in Papa New Genia in 1998 and on the Sumatra Island in Indonesia in 2004 caused buildings to float easily. The earthquake measuring 9 Mw and the tsunami in Tōhoku area in Japan on March 11, 2011 resulted in significant economic damage as well as 15.828 casualties except for the missing [4]. After the earthquake, tsunami waves reaching heights of up to 3 - 37.9 meters occurred in the area [5]. During tsunamis, structure weight remains insufficient to resist the static and dynamic effect of water (Figure 1).

There are instances other than tsunamis in which water impacts structures such as spates and overflows, tidewater from the sea, river flooding due to unexpected level of water, excessive and fast water or mud flow due to heavy and severe rainfall, flood and/or high level of underground water (UWL) cause structures to submerge, which becomes another issue that engineers should be careful about (Figure 2).

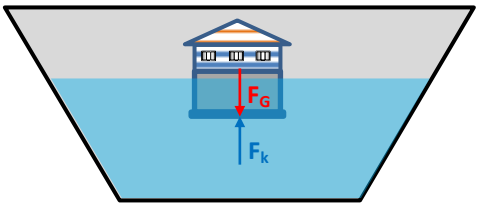

Figure 1. Structure floats when the weight of a structure (F_G) exceeds the buoyancy force (F_k) [6]

Lately, many structures in Turkey and abroad have been flooded due to the reasons mentioned above (Figure 2). Overflows are not the only reason for the submergence on the coastlines or riverbanks. Heavy and rapid rainfall, dam/aqueduct overflows, landslides and even burst water main may also lead to flooding on coastlines and riverbanks as well as in the interior parts. Floods and overflows might be destructive; since they expose structures to impact loads and leave submerged structures open to vast and intense loads. Even though these serious impacts are taken into account for stability

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(a) (b)

Figure 2. City centers that experienced floods, spates and overflows a) [7], b) May 2017, İzmir

of offshore structures and pipelines [8-10], they are not equally considered while designing structures on land.

It has been stated that nearly 90% of the property damage including the damage to the mechanical and electrical devices in the U.S. has been resulted from the overflows causing economic damage worth 3.5 million dollars annually on average [11, 12]. During storms, the water level which structures are in rises even more when wind pushes water to the shore. For example, the hurricanes Andrew, Hugo, Charley, Katrina and Rita have been found to increase the damage even more. However, the scope of this study will be the physical process, floating damage and the economic loss in structures/structure elements resulting from floods, spates and overflows as well as necessary precautions against them.

2. Forces Impacting Structures

Since floods and overflows are not generally expected inlands, the risk is often ignored during design and construction processes. However, heavy and rapid rainfall, fast melting of snow/ice, dam/aqueduct overflows, over-capacity drains and even burst water main might lead to floods and thereby submerged structures.

Three physical forces mostly impact structures affected by flood and overflow, which are hydrostatic (Figure 3a-c), hydrodynamic and impact loads. In addition to these loads, soil effects around and below foundation may worsen the condition of a structure.

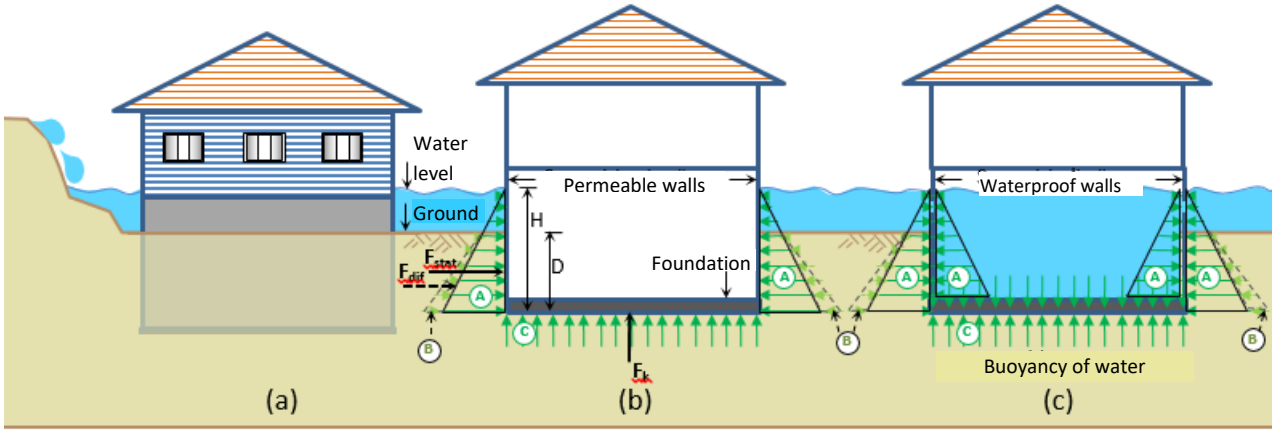


Figure 3. Hydrostatic and earth pressure forces affecting the structure a) structure affected by an overflow, b) waterproof basement walls, c) permeable basement walls

Hydrostatic loads are both lateral (pressure) and vertical (flotation) effects that arise when a structure is surrounded with water (Figure 3b-c). Hydrostatic loads are both lateral (pressure) and vertical (flotation) effects that arise when a structure is surrounded with water (Figure 3b-c).

Hydrostatic forces seen in Figure 3 which are lateral water pressure F_{stat}, lateral differential waterlogged soil pressure F_{dif}, and vertical (flotation) water pressure F_k can be calculated as shown below:

Ⓐ → Lateral Water Pressure: $F_{stat} = ½ \gamma_{water} H^2$ (1)

Ⓑ → Lateral Differential Water and Soil Pressure:

$$F_{dif} = ½ (S - \gamma_{water}) D^2 \quad (2)$$

© → Vertical Water Pressure: $F_k = \gamma (Vol)$ (3)

Here; γ_{water} is the specific weight of water (fresh water: 1 kg/m^3 and salty water: 1.025 kg/m^3); H is the distance between structure's ground and level of water (m); S is the equivalent fluid weight of waterlogged soil and water (kg/m^3); D is the vertical distance between the structure's ground and earth level (m); Vol is the volume of submerged

part of the structure (m^3).

Lateral forces result from the difference in height between water level inside and outside. When the floodwater outside a structure rises, pressure affects the walls of the structure inward (Figure 3b); when the structure is filled with water, internal and external forces even up each other (Figure 3c); and when the floodwater outside the structure subsides, pressure outward arises from the walls of the structure.

Lateral hydrostatic forces are not enough to cause deformation of a structure element or displace a structure unless there is a great difference in the level of water outside and inside of a structure (Figure 3b-c). Ensuring that the floodwater in the basement gets through the other side of the structure stabilizes hydrostatic balance mutually. If bearing elements are not strong enough, lateral hydrostatic pressure may cause permanent misalignments and damage structural elements. If there is a rapid increase or decrease in the level of water inside and outside of a building whose walls are not strong enough, the emerging difference may damage the walls or the foundation. However, when the level of water inside and outside evens up, this force disappears (Figure 3c). In other words, potential damage due to lateral pressure in a water-permeable building would be low. It should not be forgotten that if the floodwater inside a building is pumped out to the waterlogged soil, lateral pressure may arise again towards the basement walls which may be damaged by collapsing inward due to exceeding the structural capacity.

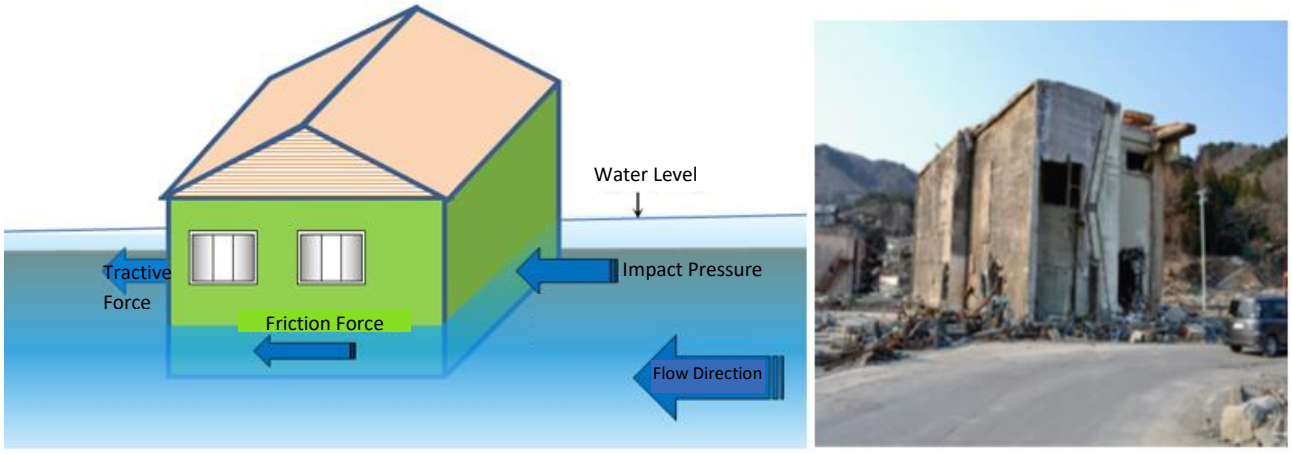
Vertical hydrostatic forces are not risky for safely-built structures. Yet, when a basement floor, an enclosed volume, is submerged during construction, buoyancy force may be worrisome if the vertical hydrostatic force exceeds the structure weight (Figure 1, 3b-c).

During a flood, the water flowing around a structure creates hydrodynamic and impact loads on the structure (Figure 4a). Lateral hydrodynamic force (F_{dyn}) is calculated as follows [13]:

$$\text{Lateral Drag Force: } F_{dyn} = C_d \rho V^2/2 A \quad (4)$$

Here, ρ is the specific gravity of water; V is the velocity of flowing water, A is the surface area in the direction of flow; C_d is the resistance coefficient against drag, which depends on the width and the depth of a structure against water.

While floodwater is flowing around a structure, friction at the structure's side elements, front impact in the direction of surface flow and absorption at the back side of the structure are the hydrodynamic loads (Figure 4a). Especially when lateral hydrodynamic pressure, which increases in parallel with the intensity of water, is combined with impact loads, it may be damaging, destructive and/or overturning for structural elements (Figure 4b).



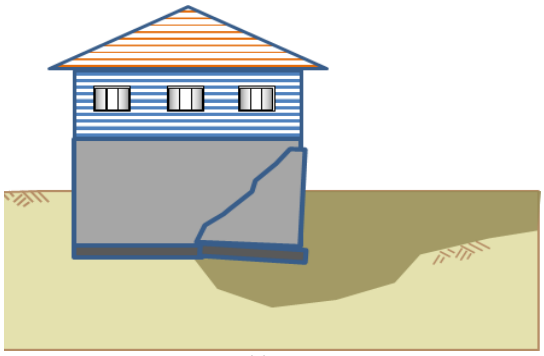
(a) (b)

Figure 4. a) Hydrodynamic and impact loads, b) overturning of the structure due to these loads [13]

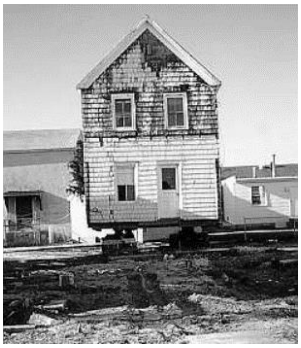
3. Other Impacts

In addition to the direct physical forces on the structure, fast-flowing water may worsen the situation by wiping away the soil supporting the foundation. In a completed structure, another way to help decrease unbalanced lateral and vertical loads to walls and foundation is to tighten the fill area contacting the structure. Otherwise, the filling around the structure may suffer from partial or complete erosion with floodwater, which might bring about serious consequences (Figure 5a-b). Erosion of the soil the structure is on depends on several factors such as soil slope; soil's being sandy or soft silty, which may change the excavation speed and ease. If erosion occurs, it may decrease the bearing capacity of the structure and thereby causing structural elements to collapse partially or completely.

Also, unless liquid storage systems are designed to resist crushing pressure and buoyancy force, they may be susceptible to overflows.



(a)



(b)

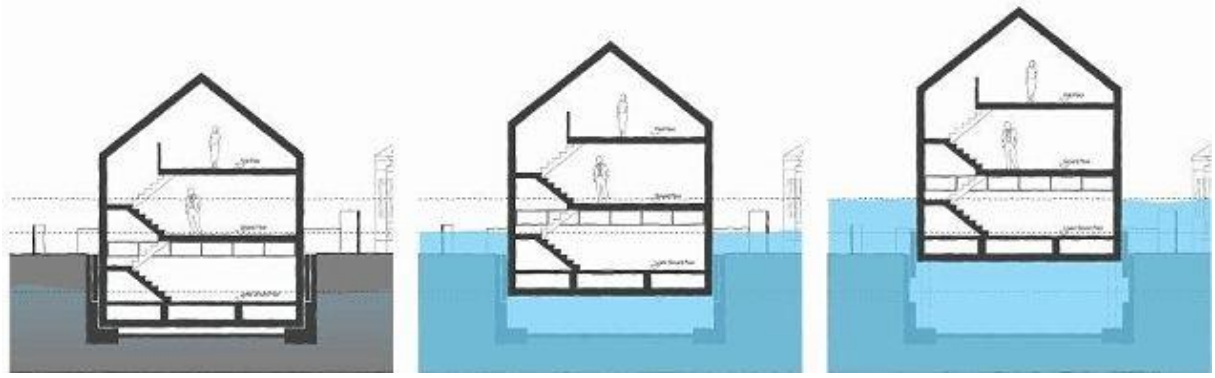
Figure 5.a, b) Soil loss due to water erosion

While distribution pipes are closed pressure system that can relatively resist high exterior and interior pressures, liquid or fuel tanks are designed to resist only interior pressures, which may result in damage during overflows. Liquid tanks that are not specifically designed for the conditions during submergence may be crushed when exposed to exterior pressure. Several tanks/stores/manholes that are placed underground without any attachment (Figure 6a) may get damaged in various ways if they are subjected to intense water load (Figure 6b).

One may ask if there is another way to deal with hydrostatic and hydrodynamic forces in areas that are frequently exposed to floods and overflows. One way to avoid this situation is to prefer designing structures compatible with nature that can move up and down concurrently with the cycle of water rise. That's why, the research and construction of amphibious structures have been on the rise [9, 14]. Amphibious buildings are relatively cheap structures that can work with water and float up when needed, rather than resisting the forces induced by water. Amphibious structures are expected to move only vertically, which also means lateral movement is prevented (Figure 7a-c, 8).

(a) (b)

Figure 6. a) Underground storage that can float up during an overflow, b) manhole that can move up with the vertical force of water [13]



(a) (b) (c)

Figure 7. Floating structures' a-c) up-down movement

Figure 8. Baca Architects ® practices

4. National/International Standards and Regulations regarding the Issue

When international publications are examined, various standards regarding the precautions against the hydrostatic and hydrodynamic effects of water on structures can be found [15-22]. To exemplify, according to Eurocode 1, 2.6. Section- 4.6., *"In case of exceedance of the water level stated in the project due to possible overflows or accidents during construction, static pressure, flotation and lateral forces may occur. Thus, these effects should be considered during design or precautions should be taken to prevent them*" [21]. According to Eurocode 7, 1. Section- 2.4.7.1., it should be confirmed with calculations that *"the limit of uplift movement of the structure due to buoyancy will not be exceeded"* [22]. Eurocode 7, 1. Section - 10.1. conditions that *"It should be certain that the structure will not move on account of buoyancy force"*. Also, in Eurocode 7, 1. Section- 12.5., it is stated that *"the possibility of flotation should be considered when light materials are used"*.

As for the national publications, in 2007 Specification for Buildings to be Built in Seismic Zones under the heading of Dynamic Active and Passive Earth Pressures, *" In addition to static earth pressure, additional dynamic active and passive earth pressure occurs in case of an earthquake and the change in this pressure through ground height*" is defined in equation in the Specification- 6.6 [22]. In the mentioned equation that gives active and passive pressure, "*if the ground is submerged, instead of γ (dry unit weight of the ground), γ_b will be taken into account; when the ground is waterlogged, instead of γ, γ_s (waterlogged unit weight of the ground) will be considered, and hydrodynamic pressure of water will also be calculated"*. Moreover, in the Bridge Design Principles published by the Ministry of Transportation, it is stated that "every element that is submerged will be taken into account as the buoyancy force comprising of static pressures" [24]. In another study regarding port structures, vertical and inertia forces have been defined [25]. A regulation dated 18.08.2007 and numbered 26617 has been issued to regulate necessary rules and minimum conditions to evaluate the earthquake performances of the present coastal-port, railway and airport structures as well as earthquake-resistant design of the ones that will be built, enlarged and changed in the future [26]. Under the head of 2.2.2.2.7 in the regulation, it is stated that *"buoyancy force will be considered only in vertical load combinations"* in port structures. There is also another study mentioning the principles published by the Ministry of Transport, Maritime and Communications that include coastal, port and marine structures [27]. As is seen, except for coastal, port and marine structures, there is no national regulation or standard stating that stability calculations of structures against flotation should be taken into account.

As a result of the examinations, on the national level, considering, analyzing and controlling the above-mentioned effect is only included in the technical specification published by Iller Bank [27]. In this specification, under the head of 2.6.2., it is stated *"flotation of structures will be checked depending on the level of underground water"*, and the head of 2.8.4.4. mentions *"stability analyses that call for the consideration of the most adverse water level and seismic loads during construction and use periods for the safety factors of overturning and flotation*". In the same specification, under the heads of 2.8.4.4.2 and 2.8.4.2.3, the condition of "consideration of stability calculations against flotation of a structure in case of elevation of surface or underground water or the elevation of both of those" is stipulated.

5. Precautions to be Taken

It will be useful to include the main points below for buildings other than coastal, port and marine structures in the national regulations and standards.

- Stability of structures should be ensured in a way to prevent flotation, collapse or lateral movement caused by hydrodynamic and hydrostatic loads including

buoyancy effect.

- Engineers should make sure with calculations that all structural elements can resist hydrostatic and hydrodynamic forces including the buoyancy effect in a possible overflow. In this sort of calculations, moving load should not be included in the structure weight. Design load combinations should be evaluated by including overflows.
- If the structure weight remains insufficient to resist lateral and vertical buoyancy force of water, sufficiency of elements that can resist these forces (mechanical connections between the ground and foundation, lateral joint systems, tension piles etc.) should be demonstrated.
- It should be made sure that these forces should be considered not only for structures but also for all the elements that are underground (storages, tanks, manholes, etc.), and that materials which can resist these forces should be preferred.
- The soil or filling material on the bottom of and around a structure should be condensed that can resist erosion.

6. Conclusions

When national publications are analyzed, it is seen that the standards regarding the necessary precautions and design principles for hydrostatic and hydrodynamic effect of water on structures apply to port structures only. It is of utmost importance to include the conditions and guidelines regarding the stability calculations against flotation of all structures in national regulations and standards

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Research Article

Effective relative storey drift limits in flexible jointed infill wall applications

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ABSTRACT

Relative storey drifts is limited by earthquake codes for earthquake safety of structures. In 2016 Turkish Earthquake Code (TEC 2016), which has yet in draft, the criteria for delimitation of relative story drifts have been specified. Compared to the previous ones, this earthquake code included the use of flexible jointed infill wall - frame joints which affect the relative storey drift limit. In this study, the limitation rules of the effective relative storey drifts are explained in detail in the case of the use of flexible jointed infill wall-frame joints specified in the section "Calculation and Limitation of Effective Relative Storey Drifts" of the TEC 2016. In addition, the maximum allowable effective storey drifts are calculated separately for each province center.

1. Introduction

Due to the fact that Turkey is located in the earthquake-prone area, the earthquake resistant structural design concept has a great importance in our country. Earthquake resistant structural design rules are determined by earthquake regulations. The earthquake regulations updated in the light of experiences obtained from earthquakes and scientific studies are in continuous development. TEC 2016, which is still in draft form, contains important changes according to previous earthquake codes. The limitations of the relative storey drifts and the application of the flexible jointed infill wall are the changes of this regulation [1].

In the design stage of a building, infill walls are one of the most complicated components to predict the effect on the building although there are several techniques to insert them to the building model [2,3]. The experiences obtained from the last earthquakes show that infill walls changes the dynamic behavior and damage mechanism of the buildings [4-8]. To overcome the problems caused by infill walls, flexible connections between infill wall and surrounding frame were proposed by researchers [9-11]. Flexible infill – frame connection method was also included to the 2016 TEC draft. Application of the flexible or conventional joints changes the relative storey drift limits [1].

Relative storey drifts is limited by earthquake codes in many countries [12]. These limitations are determined according to different rules in each code [13-15]. The effects on the lateral drifts of the structure and the damages taken during the earthquake of the infill walls were ignored in many earthquake codes including TEC 2007 [16] (2007 Turkish Earthquake Code) which is in force in our country. However, from the 1960s, in some countries' earthquake codes, it is taken into account in limitation of relative storey drifts. One of the important innovations in the draft TEC 2016 is the arrangement of the infill walls to avoid damage by determining the relative storey drift limits separately according to infill wall – frame joint types such as flexible jointed and adjoined [1,12].

In TEC 2016 draft, a relative storey drift limit interval involving all buildings can be defined by changing the parameters such as storey height, natural period, local site class and parameters depends on location of building. In this study, it was aimed to reveal the allowed maximum relative storey for buildings to be designed with flexible jointed infill wall – frame connection according to TEC 2016. For the parameters determining the relative storey drift limits, the storey height is fixed to 3 meters and the other parameters are arranged to obtain the maximum relative storey drift limit. Thus, the relative storey drift limit for each provincial center with latitudes and

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longitudes is determined for a height of 3 meters.

2. Limitation of Effective Relative Storey Drifts in TEC 2016 Draft

In TEC 2016 draft, rule of the limitation of effective relative storey drifts depends on some parameters such as storey height, type of infill wall – frame joint (adjoint or flexible jointed), natural period of building, distance to active fault plane, local site class, design spectral acceleration coefficient [1].

Limitation of effective relative storey drifts is calculated according to Equation (1) when the infill walls are manufactured adjoined to the frame and according to Equation (2) when flexible joints are used between the infill wall and frame.

$$\lambda \frac{\delta_{i,max}^{(X)}}{h_i} \leq 0.008 \quad (1)$$

$$\lambda \frac{\delta_{i,max}^{(X)}}{h_i} \leq 0.016 \quad (2)$$

In these equations, h_i is the storey height, $\delta_{i,max}^{(X)}$ is the maximum value of the effective relative story drift of the i^{th} floor of the building in X direction, λ represents the ratio of elastic design spectral acceleration calculated according to earthquake DD3 (earthquake return period of 72 years) to elastic design spectral acceleration calculated according to earthquake DD2 (earthquake return period of 475 years) (Equation 3).

$$\lambda = \frac{S_{ae}(T)_{DD3}}{S_{ae}(T)_{DD2}} \quad (3)$$

One of the important changes in the calculation of effective relative storey drifts in the TEC 2016 is the inclusion of elastic design spectral accelerations. There is also a significant difference in the calculation method of the elastic design spectral accelerations at TEC 2016. The calculation of the elastic design spectral acceleration is also included in this study since the λ coefficient is obtained using the elastic design spectral accelerations in the calculation of the allowed maximum effective relative storey drifts.

In the calculation of the elastic design spectral acceleration, first of all, from the earthquake hazard map, the hazard map spectral acceleration coefficients S_S for the short period and S_1 for the period of 1 second are taken from the location at which the considered structure is to be constructed. Using the hazard map spectral acceleration coefficients, the design spectral acceleration coefficients S_{DS} and S_{D1} are obtained using Equation (4) and Equation (5).

$$S_{DS} = S_S \times F_S \quad (4)$$

$$S_{D1} = S_1 \times \gamma_F \times F_1 \quad (5)$$

In these equations, F_S and F_1 are the local site effect coefficients, and γ_F is the coefficient of distance of the faultline. The local site effect coefficients F_S and F_1 are obtained from Table 1 for the short period zone and from Table 2 for the 1 second period zone using the local site class and hazard map spectral acceleration coefficients. The coefficient of distance of the faultline is calculated according to the cases given in Equation (6). In this equation, L_F is the distance to the fault plane. γ_F is taken as "1" for DD-3 earthquake ground motions in this study [1].

Table 1. Local site effect coefficients for short period zone (TEC 2016, Table 2.1)

Local Site Class	Local Site Effect Coefficient for Short Period Zone F_S					
	$S_S \leq 0.25$	$S_S=0.5$	$S_S=0.75$	$S_S=1.0$	$S_S=1.25$	$S_S \geq 1.5$
ZA	0.8	0.8	0.8	0.8	0.8	0.8
ZB	0.9	0.9	0.9	0.9	0.9	0.9
ZC	1.3	1.3	1.2	1.2	1.2	1.2
ZD	1.6	1.4	1.2	1.1	1.0	1.0
ZE	2.4	1.7	1.3	1.1	0.9	0.8
ZF	Site-specific soil behavior analysis will be performed.					

Table 2. Local site effect coefficients for 1.0 sec. Period (TEC 2016, Table 2.2)

Local Site Class	Local Site Effect Coefficient for 1.0 sec. Period. F_1					
	$S_1 \leq 0.1$	$S_1=0.2$	$S_1=0.3$	$S_1=0.4$	$S_1=0.5$	$S_1 \geq 0.6$
ZA	0.8	0.8	0.8	0.8	0.8	0.8
ZB	0.8	0.8	0.8	0.8	0.8	0.8
ZC	1.5	1.5	1.5	1.5	1.5	1.4
ZD	2.4	2.2	2.0	1.9	1.8	1.7
ZE	4.2	3.3	2.8	2.4	2.2	2.0
ZF	Site-specific soil behavior analysis will be performed					

$$\begin{aligned} \gamma_F &= 1.2 && L_F \leq 15km \\ \gamma_F &= 1.2 - 0.02(L_F - 15) && 15\ km \leq L_F \leq 25km \end{aligned} \quad (6)$$

Spectrum characteristic periods are calculated according to Equation (7). The natural period is denoted by T , and the transition period to the constant displacement region T_L is 6 seconds. Using this obtained data, the horizontal elastic design spectral accelerations are calculated according to the cases given in Equation (8).

$$T_A = 0.2 \times \frac{S_{D1}}{S_{DS}} \quad (7)$$

$$T_B = \frac{S_{D1}}{S_{DS}}$$

$$\begin{aligned} S_{ae}(T) &= \left(0.4 + 0.6\frac{T}{T_A}\right) \times S_{DS} && (0 \le T \le T_A) \\ S_{ae}(T) &= S_{DS} && (T_A \le T \le T_B) \\ S_{ae}(T) &= \frac{S_{D1}}{T} && (T_B \le T \le T_L) \\ S_{ae}(T) &= \frac{S_{D1} \times T_L}{T^2} && (T_L \le T) \end{aligned} \quad (8)$$

3. Limitation of Effective Relative Storey Drifts in TEC 2016 Draft

In this study, the maximum effective relative storey drifts allowed for all provincial centers were calculated according to the rule in the section "*Limitation of effective relative storey drifts*" in the TEC 2016 draft. The storey heights in the calculations were determined to be 3 m, using statistical study by Azak et al. [17]. The variable parameters are the natural period and the hazard map spectral acceleration coefficients which vary depending on the location of the structure.

ZA and ZE local site classes have been used as strong and weak grounds defined in the TEC 2016 draft for the understanding of the effect of the site class on limiting the effective relative storey drifts. The initial value of the natural period, which is another effective parameter for limiting the effective relative storey drift, is selected as 0.2, which is increased by 0.1 intervals to calculate the maximum effective relative storey drifts for each province. The abbreviations for each case that is calculated are shown in Table 3. The maximum effective relative storey drifts calculated for cases where the infill wall-to-frame joint is flexible jointed are shown in Table 5 for each provincial center according to natural period and local site class. The latitudes and longitudes of the provincial centers where the effective relative storey drift limit is calculated are also presented in Table 4.

Table 3. Parameters and abbreviations

Abbreviation	Local Site Class	Natural Period
D2A	ZA	T=0.2
D3A	ZA	T=0.3
D4A	ZA	T=0.4
D5A	ZA	T ≥0.5
D4E	ZE	0.2≥ T ≥0.4
D5E	ZE	T=0.5
D6E	ZE	T=0.6
D7E	ZE	T=0.7
D8E	ZE	T=0.8
D9E	ZE	T=0.9
D10E	ZE	T≥1.0
Dmax	Maximum effective relative storey drift	

Table 4. Latitude and longitude of provincial centers where calculations are made

Province	Latitude	Longitude	Province	Latitude	Longitude	Province	Latitude	Longitude
Adana	37.1075	35.3825	**Giresun**	40.9177	38.3844	**Samsun**	41.2908	36.3361
Adıyaman	37.7628	38.2756	**Gümüşhane**	40.4594	39.4803	**Siirt**	37.9274	41.9422
Afyon	38.7573	30.5382	**Hakkâri**	37.5774	43.7366	**Sinop**	42.0266	35.1512
Ağrı	39.7193	43.0509	**Hatay**	36.2026	36.1602	**Sivas**	39.7505	37.015
Amasya	40.6562	35.8373	**Isparta**	37.767	30.5535	**Tekirdağ**	40.9786	27.5152
Ankara	39.9208	32.854	**İçel**	36.781	34.5877	**Tokat**	40.314	36.5513
Antalya	36.8869	30.7062	**İstanbul**	40.9878	29.0368	**Trabzon**	41.0064	39.7109
Artvin	41.1812	41.8205	**İzmir**	38.419	27.1277	**Tunceli**	39.0758	39.5337
Aydın	37.8471	27.8437	**Kars**	40.601	43.0944	**Şanlıurfa**	37.1601	38.7989
Balıkesir	39.6474	27.8864	**Kastamonu**	41.3777	33.7763	**Uşak**	38.6742	29.4057
Bilecik	40.1426	29.9793	**Kayseri**	38.7227	35.4869	**Van**	38.5038	43.3955
Bingöl	38.8832	40.4929	**Kırklareli**	41.7341	27.2191	**Yozgat**	39.8221	34.8081
Bitlis	38.4053	42.1079	**Kırşehir**	39.1462	34.1606	**Zonguldak**	41.4549	31.7886
Bolu	40.7327	31.6087	**Kocaeli**	40.7651	29.9445	**Aksaray**	38.3703	34.0272
Burdur	37.7183	30.2822	**Konya**	37.8718	32.5005	**Bayburt**	40.2593	40.2268
Bursa	40.1972	29.0615	**Kütahya**	39.4192	29.9853	**Karaman**	37.1701	33.223
Çanakkale	40.15	26.4027	**Malatya**	38.3487	38.3189	**Kırıkkale**	39.8437	33.5056
Çankırı	40.6002	33.6164	**Manisa**	38.6139	27.4337	**Batman**	37.8999	41.1311
Çorum	40.55	34.9539	**K. Maraş**	37.5775	36.9266	**Şırnak**	37.5212	42.4556
Denizli	37.7829	29.0963	**Mardin**	37.321	40.725	**Bartın**	41.6265	32.3299
Diyarbakır	37.9367	40.2075	**Muğla**	37.2152	28.3639	**Ardahan**	41.113	42.7022

Province	Latitude	Longitude	Province	Latitude	Longitude	Province	Latitude	Longitude
Edirne	41.6769	26.5529	**Muş**	38.7449	41.4998	**Iğdır**	39.9233	44.0457
Elazığ	38.6749	39.2208	**Nevşehir**	38.627	34.7207	**Yalova**	40.6585	29.2743
Erzincan	39.7468	39.491	**Niğde**	37.9703	34.6769	**Karabük**	41.1956	32.6231
Erzurum	39.9056	41.2684	**Ordu**	40.9845	37.8758	**Kilis**	36.7155	37.1141
Eskişehir	39.7658	30.5238	**Rize**	41.0271	40.5177	**Osmaniye**	37.0747	36.2465
Gaziantep	37.063	37.3792	**Sakarya**	40.8511	30.3164	**Düzce**	40.8403	31.1546

When the drift values obtained according to the natural periods are examined, a linear relationship cannot be established between the period and the maximum effective relative storey drifts. In some regions, higher drift values are obtained in buildings with higher natural periods, while in some regions, higher drift values are obtained in buildings with lower natural periods. The hazard map spectral acceleration coefficients vary according to the geological conditions and the fact that the horizontal elastic design acceleration spectrum is not linear cause a lack of a proportion or tendency in the change of the displacement to the period.

It has been observed that the effective relative storey drift limit differs between 0.2 - 0.5 period intervals for ZA local site class, and does not change with larger period values greater than 0.5. In the calculations made according to the ZE local site class, it is seen that the effective relative storey drift limit changes between 0.2 - 0.4 period interval and no change in period values larger than 1.0, and the drift limit changes in 0.4 - 1.0 period interval.

Table 5. Effective relative storey drift limits for flexible jointed wall-to-frame connection (mm)

Province	D2A	D3A	D4A	D5A	D4E	D5E	D6E	D7E	D8E	D9E	D10E	Dmax
Adana	135.1	127.6	127.6	127.6	92.6	98.2	117.9	119.8	119.8	119.8	119.8	135.1
Adıyaman	123.6	123.6	155.4	155.4	81.0	81.0	90.8	105.9	121.0	126.3	126.3	155.4
Afyon	135.1	155.5	155.5	155.5	73.8	84.5	101.4	118.3	126.9	126.9	126.9	155.5
Ağrı	125.4	125.4	134.8	134.8	84.8	84.8	93.9	109.5	119.8	119.8	119.8	134.8
Amasya	122.3	126.9	154.5	154.5	66.6	66.6	66.6	77.8	88.8	99.9	104.4	154.5
Ankara	126.2	126.2	129.3	131.1	112.5	112.5	112.5	115.5	126.3	126.3	126.3	131.1
Antalya	120.0	117.5	117.5	117.5	80.0	84.4	101.3	105.6	105.6	105.6	105.6	120.0
Artvin	134.2	122.0	117.4	117.4	106.2	106.2	111.7	111.7	111.7	111.7	111.7	134.2
Aydın	140.2	180.1	180.2	180.2	67.3	67.3	72.9	85.0	97.2	109.4	113.4	180.2
Balıkesir	130.6	144.0	144.0	144.0	71.1	71.1	81.8	95.4	109.0	109.2	109.2	144.0
Bilecik	116.9	116.9	131.6	131.6	77.8	77.8	79.2	92.4	105.6	109.0	109.0	131.6
Bingöl	120.6	150.0	157.3	157.3	65.2	65.2	65.2	75.3	86.0	96.7	99.8	157.3
Bitlis	121.5	117.1	111.8	111.8	76.7	76.7	84.2	95.1	95.1	95.1	95.1	121.5
Bolu	131.6	158.2	177.8	177.8	65.4	65.4	65.7	76.6	87.6	98.5	108.0	177.8
Burdur	136.3	167.2	167.2	167.2	71.4	79.8	95.8	111.8	125.4	125.4	125.4	167.2
Bursa	128.0	135.4	144.0	144.0	70.5	70.5	77.1	90.0	102.8	107.0	107.0	144.0
Çanakkale	114.3	114.3	112.4	112.4	68.1	68.1	70.2	81.8	85.2	85.2	85.2	114.3
Çankırı	129.4	129.4	153.3	153.3	75.3	75.3	78.7	91.8	105.0	115.8	115.8	153.3
Çorum	121.3	121.3	142.6	142.6	74.6	74.6	76.5	89.2	102.0	110.1	110.1	142.6
Denizli	124.7	151.1	151.1	151.1	65.8	65.8	76.7	89.5	102.3	107.6	107.6	151.1
Diyarbakır	110.8	110.8	110.8	110.6	102.6	102.6	102.6	102.6	103.6	103.6	103.6	110.8
Edirne	149.2	149.2	118.3	118.3	118.6	118.6	118.6	109.1	109.1	109.1	109.1	149.2
Elazığ	127.9	128.0	128.0	128.0	69.8	69.8	75.0	87.4	90.9	90.9	90.9	128.0
Erzincan	139.0	156.5	179.8	179.8	67.1	67.1	67.1	77.3	88.3	99.4	109.6	179.8
Erzurum	151.7	153.9	161.2	161.2	73.3	73.3	76.2	88.9	101.6	111.2	111.2	161.2
Eskişehir	148.6	148.6	150.0	150.0	87.3	87.3	94.1	109.7	123.4	123.4	123.4	150.0
Gaziantep	122.6	122.6	119.4	119.4	102.0	102.0	102.0	109.9	109.9	109.9	109.9	122.6
Giresun	131.4	131.4	118.4	118.4	110.2	110.2	110.2	109.3	109.3	109.3	109.3	131.4

Province	D2A	D3A	D4A	D5A	D4E	D5E	D6E	D7E	D8E	D9E	D10E	Dmax
Gümüşhane	129.0	129.0	116.2	116.2	101.8	101.8	101.8	104.3	104.3	104.3	104.3	129.0
Hakkari	134.3	156.6	156.6	156.6	74.3	84.5	101.4	118.2	130.3	130.3	130.3	156.6
Hatay	152.3	178.7	186.3	186.3	74.1	74.9	89.8	104.9	119.8	129.8	129.8	186.3
Isparta	123.9	145.8	145.8	145.8	71.3	84.3	101.2	118.0	125.3	125.3	125.3	145.8
İçel	135.0	129.8	116.8	116.8	124.0	124.0	118.3	118.3	118.3	118.3	118.3	135.0
İstanbul	119.6	132.2	141.8	141.8	66.9	66.9	71.6	83.6	95.5	101.6	101.6	141.8
İzmir	129.5	152.6	152.6	152.6	67.0	67.0	74.8	87.3	99.8	107.0	107.0	152.6
Kars	125.4	120.3	109.8	109.8	96.8	96.8	101.4	103.8	103.8	103.8	103.8	125.4
Kastamonu	122.5	122.5	153.3	153.3	73.4	73.4	78.4	91.4	104.6	115.8	115.8	153.3
Kayseri	176.7	176.7	175.4	175.4	139.5	139.5	155.8	172.6	172.6	172.6	172.6	176.7
Kırklareli	139.5	139.5	116.6	116.6	116.6	116.6	116.6	108.7	108.7	108.7	108.7	139.5
Kırşehir	136.3	136.3	138.8	141.8	136.6	136.6	136.6	142.2	145.7	145.7	145.7	145.7
Kocaeli	126.2	155.8	169.4	169.4	67.9	67.9	67.9	78.2	89.4	100.6	104.5	169.4
Konya	146.4	150.6	150.6	150.6	137.0	145.5	154.2	154.2	154.2	154.2	154.2	154.2
Kütahya	170.8	170.8	167.6	167.6	85.4	85.4	94.8	110.6	126.4	127.9	127.9	170.8
Malatya	127.1	131.3	131.3	131.3	70.6	70.6	82.6	96.4	98.8	98.8	98.8	131.3
Manisa	132.4	156.0	156.0	156.0	67.0	67.0	74.5	86.9	99.3	108.1	108.1	156.0
K. Maraş	134.2	157.3	168.0	168.0	72.0	74.1	88.9	103.8	118.6	124.9	124.9	168.0
Mardin	120.0	120.0	120.0	108.8	119.8	119.8	119.8	119.8	119.0	110.6	110.6	120.0
Muğla	119.9	136.5	137.4	137.4	68.1	68.1	78.8	91.9	105.0	105.5	105.5	137.4
Muş	117.9	117.9	136.6	136.6	68.1	68.1	70.2	81.8	93.6	101.6	101.6	136.6
Nevşehir	139.8	139.8	148.6	148.6	140.9	140.9	140.9	151.0	151.0	151.0	151.0	151.0
Niğde	152.7	152.7	164.0	164.0	143.2	143.2	156.8	163.0	163.0	163.0	163.0	164.0
Ordu	119.8	119.8	119.8	119.5	105.9	105.9	105.9	105.9	107.0	107.0	107.0	119.8
Rize	162.1	128.6	117.6	117.6	112.9	112.9	112.2	112.2	112.2	112.2	112.2	162.1
Sakarya	132.0	150.4	167.5	167.5	65.5	65.5	68.2	79.5	90.9	102.3	108.9	167.5
Samsun	122.6	122.6	132.0	132.0	85.3	85.3	85.3	92.2	105.4	108.8	108.8	132.0
Siirt	128.2	130.7	137.3	137.3	84.9	84.9	100.2	116.8	124.1	124.1	124.1	137.3
Sinop	148.3	148.3	148.3	128.8	132.6	132.6	132.6	132.6	120.6	120.0	120.0	148.3
Sivas	121.9	121.9	120.0	118.6	100.3	100.3	100.3	100.3	104.6	104.6	104.6	121.9
Tekirdağ	124.0	135.0	149.0	149.0	67.5	67.5	71.7	83.6	95.5	105.2	105.2	149.0
Tokat	120.1	120.1	144.7	149.4	69.1	69.1	69.1	78.2	89.4	100.6	106.7	149.4
Trabzon	163.2	139.6	121.3	121.3	122.1	122.1	117.4	117.4	117.4	117.4	117.4	163.2
Tunceli	131.4	131.4	147.3	147.3	72.5	72.5	74.4	86.8	99.2	108.6	108.6	147.3
Şanlıurfa	129.5	129.5	129.5	141.0	129.9	129.9	129.9	129.9	134.9	141.1	141.1	141.1
Uşak	113.8	126.6	126.6	126.6	71.3	75.3	90.3	105.4	111.3	111.3	111.3	126.6
Van	135.6	139.7	142.2	142.2	83.0	83.0	98.3	114.7	123.5	123.5	123.5	142.2
Yozgat	122.8	122.8	122.8	113.1	116.6	116.6	116.6	116.6	106.6	106.3	106.3	122.8
Zonguldak	145.8	143.9	122.5	122.5	100.4	100.4	100.4	108.2	108.2	108.2	108.2	145.8
Aksaray	215.6	209.8	202.1	202.1	193.3	193.3	198.6	198.6	198.6	198.6	198.6	215.6
Bayburt	134.5	132.3	110.6	110.6	91.0	91.0	91.0	96.0	96.0	96.0	96.0	134.5
Karaman	153.0	127.4	125.4	125.4	152.1	133.8	129.4	129.4	129.4	129.4	129.4	153.0
Kırıkkale	135.2	135.2	139.4	139.4	104.9	104.9	106.4	124.2	129.8	129.8	129.8	139.4
Batman	119.5	119.5	116.5	108.0	109.6	109.6	109.6	109.6	102.6	102.6	102.6	119.5
Şırnak	149.5	168.0	168.0	168.0	79.6	94.5	113.4	132.2	141.0	141.0	141.0	168.0
Bartın	148.6	141.2	122.6	122.6	102.6	102.6	102.6	109.0	109.0	109.0	109.0	148.6
Ardahan	134.8	135.0	135.0	135.0	84.6	89.0	106.9	119.4	119.4	119.4	119.4	135.0
Iğdır	135.9	141.0	144.0	144.0	88.2	88.2	104.8	122.2	128.6	128.6	128.6	144.0
Yalova	122.2	145.4	154.2	154.2	62.9	62.9	62.9	72.6	83.0	93.4	99.3	154.2

Province	D2A	D3A	D4A	D5A	D4E	D5E	D6E	D7E	D8E	D9E	D10E	Dmax
Karabük	132.3	132.3	158.6	158.6	74.6	74.6	77.6	90.6	103.5	116.4	118.1	158.6
Kilis	131.3	131.3	149.1	149.1	94.4	94.4	98.2	114.6	131.0	131.8	131.8	149.1
Osmaniye	133.4	146.0	158.3	158.3	75.5	78.2	93.8	109.5	125.1	126.5	126.5	158.3
Düzce	140.7	156.3	169.9	169.9	66.7	66.7	68.1	79.4	90.8	102.2	108.9	169.9

4. Conclusions

In this study, according to TEC 2016 draft, maximum effective storey drift values have been calculated in varying natural periods for local site class of ZA and ZE of selected points in each city center. The following results are obtained from the drift values obtained from the calculations:

• In the vast majority of provinces, it is seen that the limits of effective relative storey drifts are higher for the ZA local site class than for the ZE local site class. However, it is unable to make generalizations because of the existence of opposite conditions.

• Where the infill wall-frame connection is flexible jointed, it is allowed to drift twice as much as the adjoined connection.

• Drift limit should be calculated for the point at which the structure will be constructed, because effective relative storey drifts depend on parameters that are not linear and have no particular tendency.

• The obtained drift limits will help to determine the gap or flexible joint sizes for the wall-frame joints to be developed.

Finally, for the flexible jointed infill wall applications, this study reveals the reduced relative storey drift limits of each city center for a wide natural period range which could be often encountered in application. It is expected that the obtained drift values would be the helpful to determine the flexible joint size.

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Research Article

Transportation planning with analytic hierarchy process and goal programming

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ABSTRACT

Transportation planning process, which requires a multi-criteria decision making a very specific decision, is one of the most important issues of metropolitan cities. There are many projects in the field of rail systems in Istanbul and some of these projects are monorail projects. Through this way, urban transportation is supported by various types of public transportation. However, it is not possible to allocate the resources to all projects at the same time. This is affected by several criteria, especially by limited budgetary constraints. In this study, monorail projects were evaluated in accordance with urban needs of Istanbul and the planning was done under three different budget scenarios. The analytic hierarchy process (AHP) was used in the evaluation process of the projects and the goal programming (GP) model was used for the selection process. As a result, the selection of the monorail projects planned for Istanbul was made.

1. Introduction

Transportation planning is an important issue to be focused on due to the growing population, the expanding city borders and the resulting traffic intensity. For a regular and good transportation, it is essential to make planning by taking into account a long process and all factors. However, unforeseen circumstances arising later can cause disruptions or revisions in planning.

In Istanbul, with its population approaching 15-16 million, urban transport projects have an important place among the other investment areas. Urban transportation is the main of the issues that are emphasized. In this field, with various transportation types and projects, many investments are made, planned and designed. Various projects are being put forward to improve the quality of life in the urban areas, such as purchasing new transportation vehicles, constructing rail system projects, projects for supporting the infrastructure, speeding up environment friendly investments, investments in culture, arts, tourism, health, social services, youth sports and education. Transportation investments are at the beginning of all these investments, and a large budget is allocated to this field.

With their high capacities, diverse rail systems, such as metro, tramway, light rail system, form the main backbone of the urban transportation. Monorail systems emerging in response to changing transportation needs have also taken its place among these rail systems.

In this study, regarding the budget constrain, selection of the most suitable projects was made among the monorail projects planned for Istanbul.

The paper consists of six sections. In the 2nd section of this study, the monorail systems are explained. While the AHP is briefly explained in the 3rd section, a brief expiration of the GP and its literature review are presented in the 4th section. Section 5 provides a solution to the established mathematical model. The summery of the study and concluding remarks are presented in the 6th Section.

2. Monorail

The Monorail is a fast, comfortable and environmentally friendly system that travels along its own route by being isolated from vehicle traffic. Monorail has applications in the urban transportation. However, it is newly included in transportation planning in our country, and has taken its

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place in urban transportation with its various advantages.

There are some academic studies about this subject in the literature. Çankaya [1] investigated the applicability of monorail for Kocaeli province in his study. Hamurcu [2] determined the most suitable route for monorail alternative projects planned for Ankara. Çalis [3] compared the characteristics of the monorail transport system with other transport systems. Division [4] conducted an application study for Adıyaman province. Tarighi [5] assessed the applicability of the monorail for the campus in terms of financial, technical and social perspective. In their studies, Ghafooripour et al. [6] examined the countries having metro and monorail applications, and evaluated the feasibility and cost effectiveness of those applications for developing countries. Das et al. [7] evaluated the effectiveness of the transportation system in terms of user satisfaction and made suggestions. Marathe and Hajian [8] talked about the ideal use of monorail in urban transportation in terms of economy, safety and environmental awareness. Zhang, et al. [9] estimated the population around Kitakyushu monorail and estimated the usage of monorail stations. Liu et al. [10] pointed out the advantages and disadvantages of monorail systems by comparing the conventional rail transport systems with the monorail system. In his study, Timan [11] emphasized that metropolitan cities would be a suitable solution for the traffic problem. He [12] referred to the properties of the straddle type monorail system and noted that the popularity of this system increased day by day. Gür et al. [13] and Taş et al. [14], made selections among different monorail projects in terms of capacity, vehicle and route for Ankara. Taş et al. [15], determined the monorail line type among three alternatives.

3. Analytic Hierarchy Process

The Analytical Hierarchy Process (AHP) is a multi-criteria decision-making method developed by Saaty. The AHP is an effective method in the decision making process because it can be understood and applied easily by decision makers [16]. The implementation steps are:

Step 1. Determination of the problem.

Step 2. Determination of the objectives of the problem or consideration of all actors, objectives and its outcome.

Step 3. Identification of the criteria for evaluation

Step 4. Structuring the problem in a hierarchy of different levels constituting goal, criteria, sub-criteria and alternatives.

Step 5. Comparing each element in the corresponding level and calibrate of them on the 1-9 Saaty scale.

Step 6. Performing calculations to find the maximum Eigen value, consistency index (CI), consistency ratio (CR).

If the CI, and CR are satisfactory, decision is taken based on the normalized values; otherwise, the procedure is repeated till these values lie in a desired range.

4. Goal Programming

The GP is one of the many models which have been developed to deal with decision-making problems related to the multiple objectives. While the decision-maker is seeking the best solution among a set of feasible solutions, this model allows taking into account simultaneously many objectives [17]. GP is first described by Charnes and Cooper [18]. Today, GP is one of the most widely used multi-criteria decision making techniques. Regarding this technique, which has been applied in various fields, Romeo, Scnieederjans and Tamiz's studies showed that it had more effective application areas. [19-23]. AHP and GP are used separately as well as they are used together. Table 1 shows the jointly use of AHP-GP. At the same time, for detailed information about the methods, these studies can be reviewed. In the classical formulation, it takes the following form:

Ω: feasible set

X_j : the input variables representing

g_i: goal leves

d_i^-, d_i^-: the positive and the negative deviations

Minimize

$$\sum_{i=1}^{p} d_i^+ + d_i^-$$

Subject to

$$\sum_{j=1}^{n} a_{ij} X_j + d_i^- - d_i^- = g_i, \quad i = 1 \ldots\ldots p \qquad (1)$$

$$X \in \Omega$$

$$d_i^-, d_i^- \geq 0, \qquad i = 1 \ldots p$$

Table 1. Jointly use of AHP -GP in the literature

Author	Year	Method	Decision Problem
Özcan et al. [24]	2017	AHP-GP-TOPSIS	Maintenance planning
Gür et al. [25]	2017	AHP-GP	Transportation planning
Gül and Eren [26]	2017	AHP-GP	Logistics
Wichapa and Khokhajaikiat [27]	2017	Fuzzy AHP-GP	Location selection
Chi [28]	2016	AHP-TOPSIS-GP	Supplier selection
Hamurcu ve Eren [29]	2015	AHP-GP	Transportation
Lin et al. [30]	2015	AHP-GP	Contractor company selection
Memarian et al. [31]	2015	AHP-GP	Water resources management
Ünal and Eren [32]	2015	AHP-GP	Staff scheduling
Özder et al. [33]	2015	TOPSIS-GP	Supplier selection
Karaman and Çerçioğlu [34]	2015	AHP-VIKOR-GP	Investment project selection

Table 2. Alternative projects

Route	Line of Route	Type	Distance (km)	Number of Wagon	Cost (Million US$)				
					Operation and maintenance costs	Km/ maintenance costs	Build+ M&E	Wagon cost	Total
M1	XXX	Monorail1	5,8	26	4	0,71	145	44,1	189
M2	YYY	Monorail2	7,7	33,2	5	0,71	92,4	56,4	149
M3	ZZZ	Monorail1	8,6	33,9	6	0,71	103,2	57,6	161
M4	CCC	Monorail1	3	28,4	2	0,71	36	48,3	84
M5	BBB	Monorail2	11	48,8	7	0,68	132	82,9	214
M6	DDD	Monorail2	3,5	46,3	3	0,73	42	78,7	121
M7	SSS	Monorail	69,3	135	49	0,71	831,6	365,5	1.197

5. Application

In this study, project selection was made for monorail which is an alternative public transportation system planned by Istanbul Metropolitan Municipality in order to improve urban transportation.

The Istanbul Transportation Master Plan was taken into consideration to determinate the alternatives. The planned seven monorail projects and their costs, lengths and number of wagons are shown in Table 2 [35]. The evaluation criteria also are shown in Table 3.

Literature review and expert opinions were used to determine the criteria related to the AHP method. Gerçek et al. [36] used 4 main criteria and 16 sub-criteria to evaluate the rail transportation network for Istanbul. Piantanakulchai [37] evaluated highway routes by using 6 main criteria and 34 sub-criteria. Brunner et al. [38] took into consideration the demographic, social and environmental factors in their analysis made for the determination of public transport routes and selection of station locations.

Table 3. Determined evaulation criteia

Criteria	Sub-criteria	Description
Economy	Constraction cost Operation cost	Includes construction costs of the projects
Environmental impact	Land structure Sensetive area	The impact of the projects on the environment
Social impact	Access to employment areas Access to education areas Population rate Access to housing Accessibility	Improvement of urban transportation
Engineering	Extensible Travel time Integration Demand level	The ensuring sustainability

Kim et al. [39] established a spatial decision support system to identify the most suitable corridor for high-speed trains. Their evaluation criteria were engineering, environment and population. The selection of project is one of the difficult decision processes of managers and transportation planners. In the literature, there are a lot of academic studies about selection of monorail projects [40-42]; selection of transport projects [43-45]; route selection [46-47], determination of mass transport type [48-50].

In Figure 1, the decision hierarchy for weighting of alternatives are shown. The results of the AHP method are given in Table 4. Then, the mathematical model is given, and the solution results are shown in Table 5.

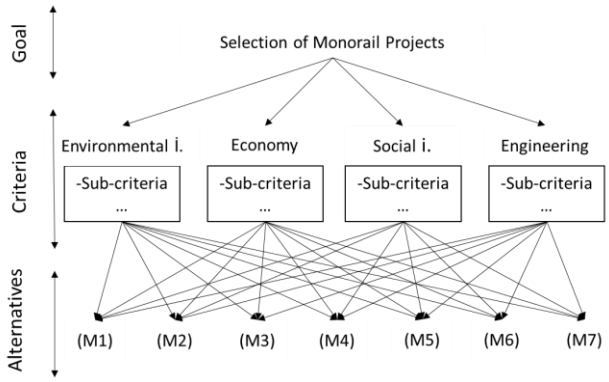

Figure 1. Decision hierarchy for AHP

Table 4. AHP important weights

Projects	The important weights of projects	Ranking
M1	0,1842	4
M2	0,2046	2
M3	0,0731	5
M4	0,1963	3
M5	0,0675	6
M6	0,2514	1
M7	0,0227	7

Goal Programming model:

M_i: Selected monorail projects(I=1,2,…..7)

d_i=deviation variables(d_i^- and d_i^+)

Objective function:

Min Z

$Pl_1 (d_1^- + d_1^+ + d_2^- + d_3^+)$

$Pl_2 (0{,}1842d_4 - + 0{,}2046d_5^- + 0{,}0731d_6^- + 0{,}1963d_7^- + 0{,}0675d_8^- + 0{,}2514d_9^- + 0{,}0227d_{10}^-)$

Constraints:

$189M_1+149M_2+161M_3+84M_4+214M_5+121M_6+1.197M_7+ d_1^- + d_1^+$ =Scenario A-B-C (Constraint of budget)

$5{,}8M_1+7{,}7M_2+8{,}6M_3+3M_4+11M_5+3{,}5M_6+69{,}3M_7+ d_2^- + d_2^+ = 108$ (Access to the farthest distance)

$4M_1+5M_2+6M_3+2M_4+7M_5+3M_6+49M_7+d_3^- + d_3^+=1$ (Minimum operation and maintenance cost)

$M_1 + d_4^- = 1$(Selection of project M_1)

$M_2 + d_5^- = 1$(Selection of project M_2)

$M_3 + d_6^- = 1$(Selection of project M_3)

$M_4 + d_7^- = 1$(Selection of project M_4)

$M_5 + d_8^- = 1$(Selection of project M_5)

$M_6 + d_9^- = 1$(Selection of project M_6)

$M_7 + d_{10}^- = 1$(Selection of project M_7)

$M_1+M_2+M_3+M_4+M_5+M_6+M_7=1$(Selection of only one project)

$M_j = 0$ veya 1; j=1, 2, …7

Table 5. Selected projects

Projects	AHP Ranking	Budget Scenario (Million US $)		
		200	500	5.000
M1	4	---	---	---
M2	2	---	---	---
M3	5	---	---	---
M4	3	x	---	---
M5	6	---	x	x
M6	1	---	---	---
M7	7	---	---	---

Goal programming model is solved with the IBM ILOG program. In Table 5, it is seen that the M4 project is selected under the $ 200 million budget constraint and the M5 project is selected under the $ 5,000 million budget constraints.

6. Conclusions

In the study, the monorail projects planned for Istanbul urban transportation was selected by using AHP and goal programming together. Three budget scenarios were used in the evaluation. These projects was planned for the next years. Urban transportation planning is one of the most important issues of the metropolitan cities.

The importance of urban transportation is emphasized and new projects are put forward to improve the traffic.

Because of inclusion of various factors in the evaluation process and desire to achieve various goals, the analytical models are needed. Within the defined evaluation criteria and constraints, these methods provide appropriate and correct results for the decision makers. For future studies, various decision making methods such as ANP-TOPSIS can be used. Dynamic programming model can be put forward. At the same time, fuzzy logic can be included in the decision process.

Increasing the number of criteria by allowing more projects to be assessed in the same model will also increase sensitivity in taking more beneficial results. Usage of resource is important for public institutes and in the decision process including various constrain. So, in this area analytic models can also be used.

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Research Article

Prioritization of high-speed rail projects

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ABSTRACT

In recent years, intercity transportation has gained momentum towards high-speed rail in Turkey. Ankara-Konya, Ankara-Eskişehir and Istanbul lines were opened for high-speed transportation in this area. There are still high-speed train lines under construction. At the same time, there are also various high-speed rail projects that will be started soon and are in the designing process. However, these projects require a big budget. Because of this, it is not possible to carry out all the projects and some projects are carried out gradually. In this study, prioritization of the high-speed rail projects was done by using the analytical hierarchy process (AHP). As a result of prioritization made through criteria determined by literature review and expert opinion, evaluations are made.

1. Introduction

In the travel route between cities, serious efforts are being made to reduce the travel time and to provide a fast, comfortable and safe transportation. Therefore, in order to increase the share of railway in transportation, high speed rail (HSR) and rapid train investments have been accelerated in our country.

Significant investments in the railway sector have been made in Turkey in recent years. Among these investments, high-speed rail investments are the most noteworthy. In our country, passenger transportation with HSR was started in 2009 and it is currently maintained by the Turkish State Railways (TCDD) on HSR lines between Ankara-Istanbul, Ankara-Eskisehir, Ankara-Konya and Eskisehir-Konya routes. Among the objectives of TCDD, increasing HSR lines and expanding the passenger transportation with HSR have an important place. In addition to the completed lines, HSR investments are continuing on different lines centered to Ankara. It is necessary that both the railway and the vehicles of the HSR which provide the possibility of travel at high speeds should be suitable for these speeds.

With the construction of a new railway line, the construction of signaling and electrification systems, security measures and vehicles having high speed capability, HSR investments have an important start-up cost.

HSR is built on a straight route as far as possible. Although this corresponds to a shorter line length between the two settlement areas compared to the conventional railway, the construction of tunnels, bridges and viaducts built in the construction of these lines increases the costs of construction [1]. Therefore, these projects require a large budget. Because of this, it is not possible to carry out all the projects and some projects are carried out gradually.

There are various reasons for the acceptance and widespread use of high-speed rails. These trains are preferred especially among cities with dense population due to their high speeds and transportation capacity [2].

In addition to this, the most important advantages of HSR are time saving in travel process, its contribution to regional development, being more economical compared to air transport and presenting safer transportation alternative compared to land vehicles.

Today, developed countries focus on fast, convenient, economical, safe and environmentally friendly transportation systems and aim to take the best solution on the basis. High-speed railways, as a system that can provide the most appropriate solution to the desired features, rapidly take their place among transportation modes and increase their share in all transportation modes [3]. Achieving all investments at the same time requires prioritization among projects, sorting between projects or execution of decision mechanisms for selecting process. With their analytical processes, multi-

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criteria decision methods, which are frequently used in decision making processes, provide easy and effective results. AHP, analytic network process (ANP), TOPSIS, VIKOR, Promethee are some of these decision processes.

These methods, which are frequently used in transportation problems, also reveal the experience of the experts around the criteria determined for decision makers and the evaluation process according to the given data.

There are some studies on this area in the literature. Ahern and Anandarajah [4] have developed a model for prioritizing rail system investment projects. Taking in consideration the financial, economic, social, environmental and traffic impacts and benefits of the projects, Tsamboulas [5] has developed a model for prioritizing transport projects. Longo et al. [6] have developed the AHP and ANP models and compared their main characteristics. They have also carried out a real selection work for a new guided system connection.

Wey and Wu [7] have proposed a mixed application of Delphi, ANP and goal programming for the selection of transportation infrastructure projects. By using ANP in prioritization of rail-system infrastructure investment projects, Macura et al. [8] have made prioritization on the benefit-cost ratio, travel time, line capacity utilization, traffic volume, and international agreement harmonization criteria among 5 alternative projects.

Saat and Aguilar Serrano [9] have applied a multi-criteria implication in choosing high-speed train routes. They used the cost, potential user and gross domestic product criteria in the evaluation process.

By using a multi-criteria approach, for the high-speed train route, Sperry et al. [10] have made evaluation taking in to account the main criteria of cost, population, environmental impacts and demand.

Hamurcu and Eren [11], established a goal programming model for urban rail transport project by using AHP and ANP with four main criteria. Rail systems projects selection were made. In their another study [12], they conducted project selection among metro, monorail, tramway and light rail systems by using AHP-GP mathematical model for urban transport.

Project selection is one of the difficult decision-making processes of transportation planners and it needs multi-criteria evaluation process.

There are some studies in the literature about project selection; selection of monorail projects [13-16]; determination of line type [17]; selection of transportation projects [16-20]; technology selection [21,22], route selection [23,25].

2. Analytic Hierarchy Process Method

Various techniques are applied to conduct a multi-criteria decision making process. In the literature, there are some academic studies on multi-criteria decision-making methods, such as strategy selection with ANP and Promethee [26], selection of third-party logistics (3PL) company in an online shopping site with AHP-TOPSIS [27], analysis of television news using AHP-TOPSIS-Promethee [28], personnel selection by using AHP-Promethee [29], supplier selection with ANP-GP [30], conference selection [31]; journal selection with ANP [32], stock control [33], AHP and TOPSIS for maintenance strategy selection[34], selection of high speed rail station location with AHP [35] and transport planning [36-39].

The AHP method, suggested by Saaty, has begun to be used in decision-making problems in various areas. This method is a decision making approach that shows the distribution of the percentages of the criteria and alternatives affecting the decision in the decision matrix created for a problem [40].

After determining the decision problem, the general steps of the AHP method are as follows:

i) Establishment of a hierarchical structure: By introducing a hierarchical structure of the decision maker, the objective is to offer an opportunity for an effective comparison of the criteria and alternatives by placing the criteria and alternatives at the lowest level. The decision problem is fully explained at this stage.

ii) Pairwise comparison matrix and relative importance weight values: In this step, relative importance weight values of the criteria are given, and a paired comparison matrix is formed.

The pairwise comparison values of the criteria are based on the evaluators' knowledge, experience and expertise, or evaluations obtained by the survey study. The values of the criteria in the pairwise comparison matrix is based on the 1-9 scale in Table 1 [41].

Table 1. The 1-9 scale used in the pairwise comparison method

Numbers	Value
1	Equal
3	Moderately more impontant
5	Strongly more important
7	Very strongly more important
9	Extremely more important
2, 4, 6, 8	İntermediate values

Eigenvector value and consistency ratio: Between criteria and for each crierion, equation (1) is used in the calculation of the eigenvector value (wi) of the criteria in the pairwise comparison matrix of the alternatives.

$$w_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}} \quad \text{.....(1)}$$

After finding the eigenvector value of the criteria, consistency ratio, consistency indicator and eigenvalue are calculated. The Consistency Rate (CR) is a measure of the consistency between the values given at the time of the pairwise comparison. The consistency ratio should be less than 0.10. The consistency rate is calculated by using Equation (2).

$$CR = \frac{CI}{RI} \quad \text{..... (2)}$$

Equation (3) is used to calculate the Consistency Index (CI).

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad \text{..... (3)}$$

In order to calculate the value of consistency indicator; the maximum eigenvalue (λmax) must be found by using Equation (4).

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(aw)_i}{w} \quad \text{..... (4)}$$

The Random Index (RI) values (stochastic indicators) in Eq. (2) are shown in Table 2.

Table 2: Randomness index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

iii) Finding the importance weights and ranking the alternatives: These operations for the criteria are the same in the evaluation of the alternatives. The decision alternative weights obtained by matrix multiplication of the criterial weights and weights of the alternatives found for each criterion are sorted from small to large.

3. Prioritization of High-Speed Rail Projects

The information about ongoing, planned, and projected High-speed and high-speed rail project were taken from the TCDD website [42].

Ankara - İzmir High Speed Rail Project (Under Construction) (A1): This is a project that will connect İzmir, the third biggest city of our country with its industry, tourism potential and port, to Ankara. The construction of the High Speed Railway Project, which will also take Manisa, Uşak and Afyonkarahisar on the route to Ankara, is ongoing. When the project is completed, the travel time between İzmir and Ankara will decrease from 14 hours to 3 hours and 30 minutes. The infrastructure construction of the Polatlı-Afyonkarahisar section of the Ankara-İzmir HSR project is ongoing and 40% physical progress has been achieved. This line is planned to be completed in 2019. This route is shown in Fig 1.

Figure 1. Ankara - İzmir High Speed Rail Project

Ankara - Sivas High Speed Rail Project (Under Construction) (A2):The construction of the Ankara-Sivas High-Speed Rail, one of the most important axes of the railway corridor that links Asia Minor and Asian countries on the Silkroad, continues.

The high-speed rail line will be connected with Sivas-Erzincan, Erzincan-Erzurum-Kars and Baku-Tbilisi-Kars railway project. The existing Ankara-Sivas railway is 603 km and the travel time is 12 hours. With this project, which will shorten the travel time between the two cities, constructing a new high speed railway having double line, electric, signal, and suitable for a maximum speed of 250 km / h was targeted. When the project is completed, the travel time will be reduced from 12 hours to 2 hours. The HSR project will reduce the distance between Ankara and Sivas to 405 km; the ongoing infrastructure construction works on all line segments is at 75 percent level. The project is planned to be completed by the end of 2018. This line route is shown in Figure 2.

Figure 2. Ankara – Sivas High Speed Rail Project

Yerköy-Kayseri High Speed Rail Project (in the planning stage) (A3): This line will be made as double line in connection with Ankara-Sivas HSR line. It will also have electric, signaling, and capability of speeding 250 km / h between Yerköy-Şeffaatli-Kayseri, which is 142 km long.

Karaman-Ereğli-Ulukişla-Yenice Rapid Rail Project (At the projecting stage) (A4): Infrastructural and signaling constructions, project preparation works for electrification and Ulukışla-Yenice project preparation works are continuing.

Eskisehir-Antalya / Antalya-Kayseri Rapid Railway Project (At the projecting stage) (A5): For Antalya-Burdur / Isparta-Afyonkarahisar-Kütahya-Eskişehir and Antalya-Konya-Aksaray-Nevşehir-Kayseri high speed train projects, the final project preparation works are underway. It is evaluated that together with the existing HSR lines already operating, the development of conventional lines in terms of speed, security, electricity and signal, and giving importance on the conversion of single lines to double lines will be beneficial in terms of the future of the railway.

Enhancing and development of conventional lines is less costly than the construction of new HSR lines and is preferred instead of building new lines. When we look at the examples in the world, it is evaluated that in order for HSR, which have high construction and maintenance costs, to be economic, the occupancy rates shold be close to full capacity. The fact that the number of train services is as high as possible is also important in terms of the number of passengers carried. Twelve criteria have been identified in the study to evaluate alternative projects. These criteria are shown in Table 3.The hierarchy process, goals, criteria and alternatives are shown in Figure 3.

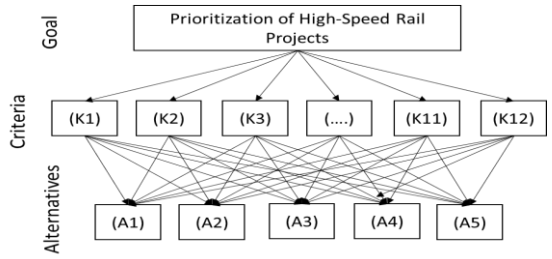

Figure 3. Decision hierarchy

Table 3. Determinated criteria

No	Criteria	Symbolic representation
1	Demand level	K1
2	Cost	K2
3	Travel time	K3
4	Speed	K4
5	Population ratio	K5
6	Regional development	K6
7	Integration	K7
8	Environmental impact	K8
9	Constraction cost	K9
10	Operating cost	K10
11	Transport efficiency	K11
12	Safety	K12

In this process, firstly each criterion is evaluated by paired comparisons among themselves and then alternatives for each criterion are evaluated by paired comparisons between each other. Table 4 and Table 5 show symbolic representations. As a result of the evaluations, the criterion weights are shown in Table 6 were found.

Table 4. Comparision of criteria

Criteria	K1	K2	…..	K11	K12
K1	1	…	…	…	…
K2	…	1	…	…	…
…	…	…	…	…	…
K11	…	…	…	1	…
K12	…	…	…	…	1

Table 5. Comparision of Alternatives

Criteria	A1	A2	A3	A4	A5
A1	1	3	3	5	3
A2	1/3	1	…	…	…
A3	1/3	…	1	…	…
A4	1/5	…	…	1	…
A5	1/3	…	…	…	1

Table 6: The important weights of critaira

No	Criteria	Weights
K1	Demand level	0,1177
K2	Cost	0,0129
K3	Travel time	0,0402
K4	Speed	0,0533
K5	Population ratio	0,0461
K6	Regional development	0,1203
K7	Integration	0,0402
K8	Environmental impact	0,1098
K9	Constraction cost	0,0637
K10	Operating cost	0,0425
K11	Transport efficiency	0,1000
K12	Safety	0,2533

The importance weights of the alternatives compared under each criterion are shown in Table 7.

Table 7: The importance weights and ranking of the projects

Alternatives	The importance weights	Ranking
A1	0,27730	1
A2	0,26087	2
A3	0,16638	4
A4	0,12198	5
A5	0,17335	3

As a result of the evaluations, the criterion weights shown in Table 7. were found. Final ranking are first Ankara-İzmir high speed rail project, second Ankara-Sivas high speed rail project and respectively Eskişehir-Antalya/Antalya-Kayseri rapid rail, Yerköy-Kayseri high speed rail project and Karaman-Ereğli-Ulukişla-Yenice rapid rail project. The Ankara-Sivas and Ankara-İzmir high speed rail lines are under construction. Hence, the result of this study is consistant.

4. Conclusions

In this study, 5 alternative high speed rail and rapid rail projects under 12 criteria were prioritized. As a result of the selection, priority was placed on the selection of ongoing lines, and a network which can be used as a basis for integration is created.These lines are the newly constructed high-speed train lines. As it is understood from this study, the use of analytical methods in the decision making process presents effective results for decision makers. The efficiency of the rail systems built for intercity transportation, especially ensuring the availability of the line has precedence. Therefore, it is necessary to evaluate it by taking into consideration of various factors.

As in this study, the use of multi-criteria decision-making methods in almost every decision point of transportation, will lead to more consistent decision-making processes and results for managers. At the same time, besides the various decision making methods, by the fuzzy evaluation scales that may be included in the process, more appropriate decisions can be taken through offering modeling opportunities which are close to the real life.

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Transportation Policies in Increasing Traffic Safety

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ABSTRACT

In our century, all economical social, cultural and touristic facilities are available through the rapid, confident and satisfactory transporting. Transportation policies are of great importance in terms of increasing productivity. Country's transport system plays an important role in revitalizing the social, cultural and economic activities of countries. Therefore, the efficient use of resources, the rapid distribution of goods and services, the development of domestic and foreign trade will only be possible with careful planning of transport and the establishment of a regular transport network. It is desirable that the transport system to be selected for passenger and freight transport should be fast, economic, safe, and environmentally friendly systems suitable for the country conditions. Transportation policies are determined in the direction of these expectations. Besides the positive results of transport systems, it brings some problems. The most important of these problems is related to traffic safety, which is also the main topic of study. There are some studies on road safety in the World and in Europe. These studies; the development of new technologies, such as the provision of road signs and traffic penalty analogies, the restriction of alcohol content, the reduction of the number of lives lost in road traffic accidents, the development of electronic driving licenses, the limitation of intelligent transportation systems and the speed of vehicles. The aim of this study is to examine the policies to increase traffic safety. As a result of this study, the applications of the policies for traffic safety and the deficiencies of the implementation point in the country of Turkey are determined and suggested.

1. Introduction

Given that the transport sector's main purpose is to present transportation requests safely at the shortest possible time and at the lowest possible cost, it is achieved by creating a sub-structure that will provide coordination between transport systems, rather than focusing on one of these purposeful systems. This necessitates the preparation of the national transport master plan. All needs, resources, social and cultural interactions for a healthy transport service should be addressed and evaluated within this planning [1].

It is desirable that the transport system to be selected for passengers and freight transport should be a fast, economical, safe, environmentally friendly transportation system suitable for the country conditions. However, it is quite difficult for a system to sum up all of these things. Each system has advantages and disadvantages over the others [2].

Turkey offers the opportunity to use all transport systems together due to its geographical location. Policies that have been implemented for many years have a large share in the resultant road transport. The share of other transportation systems is very low. Therefore, traffic safety problem on highways is increasing day by day [3-6]. 7000 people lose their lives because of road traffic accidents every year in Turkey. 3 493 people crash site in the country occurred in 2016 as a result of 185 128 mortal injury traffic accident, the cause of the accident and 3 807 people wounded after being shipped to health facilities and died within 30 days under the influence. While 48.3% of the deaths and 67.3% of the injuries occurred within the settlement area, 51.7% of the deaths and 32.7% of the injuries were out of settlement [7]. Besides, the damage caused by traffic accidents is too great to be underestimated.

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2. Traffic Safety Studies in Turkey

In recent years, with regard to traffic safety, the run-of-the-mill transportation system has a large share in the current stage. Especially in the USA, Europe and Japan, the transportation investments made mainly lead to the formation of advanced road networks. These roads, constructed with extremely high quality standards, have brought with them various problems due to the inevitable nature of development over time. Traffic safety and traffic accidents are at the top of these problems. In order arising from a traffic accident deaths occur Turkey ranks 10th in the world. Countries like Brazil, Cambodia, China, and Egypt are in the first place. In Australia, Sweden, the Netherlands and the United Kingdom, the number of traffic accidents has decreased by almost half in the last 40 years. Undoubtedly, in this situation, effective transportation policies and public opinion in these countries are showing a common action against these policies. To reduce the number of people who died due to traffic accidents and to increase traffic safety, many studies were carried out from past to present. For example, despite the fact that the number of motor vehicles in Britain doubled between 1972-1999, the death rate decreased by half [8]. Since the late 1990s, there have been discussions on many topics in Sweden and the Netherlands, which are among the best countries on road safety, in order to reduce the deaths and injuries caused by traffic accidents. Vision Zero implemented in Sweden [9, 10] and the Dutch Sustainable Security Approach aimed to design the road traffic system as self-reliant. Our loss of life occurring in traffic accidents in Turkey were more than deaths from terrorism. Preventing traffic accidents and reducing the worst possible losses starts with, above all, having a vision of national transport and traffic safety. There is not enough traffic safety culture in the country. In solving traffic problems, people, vehicles, roads, environmental factors and other factors interacting together must be considered together. Putting rules in writing is not enough to create a sustainable transport and traffic safety policy. Evaluation and planning together with training and auditing activities are required. Unfortunately, in the country, temporary solutions are being sought instead of developing permanent and sustainable measures and policies on this issue. Traffic safety is a topic that covers more than one sector and area. For this reason, many organizations and very different kinds of experts are required to participate in the solution process of this problem.

In 2001, the National Traffic Safety Program was developed in the framework of the Traffic Safety Project, funded in part by World Bank credits and partly by the Turkish Government [11]. This program has been prepared in cooperation with the Executive Board of the Traffic Safety Project, which is composed of the Ministry of Transport, the Ministry of Construction and Public Works, the Ministry of Interior, the Ministry of Health and the University of Gazi and the Swedish National Road Consultancy Organization (SweRoad). The essence of this study is to suggest the solutions to the relevant departments after the problems related to traffic safety are identified. A road safety vision is short for the first time this program has been adopted in Turkey, weed, long-term plans have been made. Unfortunately, the High Council, which must convene twice a year according to the law before and after the mentioned date, has never been able to hold a meeting and the National Traffic Safety Program cannot be misled [2].

In our country which has serious problems about road and traffic safety, big and comprehensive projects are being carried out in recent years. World Health Organization as a result of the Global Road Safety Report, released in 2009, Turkey was included, and as is most simultaneously in 10 countries of deaths in traffic collisions to increase traffic safety (this is why Road Safety referred to as 10-RS10) to carry out work has been sponsored by Bloomberg Philanthropies for an international project. In this study, which is also known as the "Global Road Safety Program", the safety belt and speed in Ankara and Afyonkarahisar pilots firstly started, there has been considerable progress on the safety belt as well as the formation of structures that will provide coordination at the national level, such as the Traffic Safety Platform[12].

The increase in the number of traffic accidents in the World and Turkey, the growing population dependent transport movements shown. However, when examined statistical reports on the number of people who lost their lives in traffic accidents occurred in Turkey, the increase in the number of human deaths occur is lower than the rate of increase in traffic accidents. The reason of this; Turkey has gained importance in the last 15 years is that the policy for the divided road construction in general. In similar reports, deaths after the accident are seen in 2015 and 2016. This is because deaths after the accident are only in 2015 and 2016, because no such statistics have been studied before. Summary information about traffic accidents occurred in Turkey in recent years is shown in Table 1.

Another factor affecting traffic accident numbers is that the amount of people in transportation demand varies according to the month. Especially in summer, the volume of traffic increases with the desire to relocate due to the holiday, which causes an increase in traffic accidents in the summer months (Table 2).

3. European Union Transportation Policies and Traffic Safety

The European Union (EU), which was founded in 1951 as the "European Coal and Steel Community" by the Treaty of Paris and the Federal Republic of Germany, Italy, France,

Belgium, the Netherlands and Luxembourg, gained a new dimension in 1957 with the decision to establish the Rome Treaty and the European Economic Community entered the process.

The European Community Commission has agreed to establish a common policy in the fields of foreign trade, agriculture and transport, through the Treaty of Rome. Articles 74 to 84 of the Rome Treaty concern transport.

In 1972, the United Kingdom (UK), Denmark and Ireland were redefined mainly for the transport policy of participation. After this date, it has also been observed that the transportation infrastructure is important. In 1973, the commission emphasized freedom in waterway transport. A report prepared in 1977, transportation market and infrastructure activities were emphasized. In the 1980s, more and more "adjustment" was emphasized.

At the Maastricht Summit, held in 1992, the powerful single European idea is a multi-faceted union. Transportation is one of the most important sectors for economic and social cohesion. We can say that EU-orienting policies emerged in the 1990s. Especially in the worrying developments in the highway and transport sector, this period has begun to come to fruition [13].

These concerns; the increase in the share of road transportation was caused by the increase in passengers and loads that cannot be avoided day by day. As a consequence of the disruption of this balance in the transportation system, the environment has been damaged in great quantities and there has been a great increase in traffic accidents. It is revealed that the losses in traffic accidents are 2.5% of Gross National Product (GNP), besides traffic congestion, air pollution and noise effects also account for 4,5% of GNP when total cost is added to the account.

Table 1. Information regarding traffic accidents occurred in Turkey
(Source: General Directorate of Public Security and General Command of Gendarmerie)

Year	Total number of accidents	Accidents involving material loss only	Accidents involving death and personal injury	Total	At accident scene	Accident follow-up
2002	439 777	374 029	65 748	4 093	4 093	-
2003	455 637	388 606	67 031	3 946	3 946	-
2004	537 352	460 344	77 008	4 427	4 427	-
2005	620 789	533 516	87 273	4 505	4 505	-
2006	728 755	632 627	96 128	4 633	4 633	-
2007	825 561	718 567	106 994	5 007	5 007	-
2008	950 120	845 908	104 212	4 236	4 236	-
2009	1 053 346	942 225	111 121	4 324	4 324	-
2010	1 106 201	989 397	116 804	4 045	4 045	-
2011	1 228 928	1 097 083	131 845	3 835	3 835	-
2012	1 296 634	1 143 082	153 552	3 750	3 750	-
2013	1 207 354	1 046 048	161 306	3 685	3 685	-
2014	1 199 010	1 030 498	168 512	3 524	3 524	-
2015	1 313 359	1 130 348	183 011	7 530	3 831	3 699
2016	1 182 491	997 363	185 128	7 300	3 493	3 807

Table 2: Number of road traffic accidents involving death or injury, persons killed and injured by months, 2016
(Source: TurkStat, Road Traffic Accident Statistics, 2016)

Month	Number of accidents involving death or injury	Number of persons killed			Number of persons injured
		Total	At accident scene	Accident follow-up (1)	
Total	185 128	7 300	3 493	3 807	303 812
January	10 891	433	229	204	18 214
February	11 110	401	197	204	17 938
March	12 952	440	202	238	19 935
April	15 533	559	256	303	24 189
May	16 388	620	290	330	26 398
June	16 692	716	336	380	27 048
July	19 857	916	458	458	35 385
August	19 704	837	392	445	33 350

September	18 344	740	360	380	31 745
October	17 006	684	319	365	26 624
November	14 857	589	284	305	23 674
December	11 794	365	170	195	19 312

(1) Includes the deaths within 30 days after the traffic accidents due to related accident and its impacts for people who were injured and sent to health facilities.

For all these reasons, besides an expensive transportation, the prevention of unacceptable external influences, namely the enhancement of security and the necessity of a rational policy, the main objective of the EU is to realize a healthy, balanced and sustainable transportation system [14]. The Netherlands, Denmark, Germany and Belgium are the countries with the highest bicycle use in Europe. In The Netherlands the bicycle percentage in the model split has been approx. 26% over the last decades. In Denmark the bicycle percentage is between 15 and 20%. In Germany on average 10% of all trips are made by bicycle. Belgium has an average bicycle percentage of not much more than 8% [15]

When the statistics of the traffic accidents shown by the tables are examined; the policies implemented in the transport sector in Turkey is seen reflections of positive results. For example, when we evaluate without the results of 2015 and 2016; it is seen that the life in traffic accidents is generally similar to the number of lost people despite the fact that there is an increase of 3 times in the number of traffic accidents coming to the square in years. The increase in the number of passengers who lost their lives in traffic accidents during the years of 2015 and 2016 can be explained by the fact that tour buses belonging to tourists are involved in traffic accidents. When the distribution of the traffic accidents arriving in the square in 2016 is examined; the increase in traffic accidents is caused by the necessity of traveling due to the tourist activities of people, the summer holidays of the schools and the increase of cultural activities and the increase of the need to transport agricultural workers.

4. Transport Policy Proposals for Traffic Safety

Traffic safety is a multidisciplinary issue that deals with different branches such as engineering, sociology, psychology, health, education, security and law. Policy makers should keep this in mind. Transportation problems are problems that concern every part of the society. It is important to be offered to the public when an investment in transportation is to be made. In order to ensure traffic safety in the country, it is listed below.

1. The use of all transport systems in integration, railway, inland waterway, short sea transport and combined transport should be given priority. In addition, transportation of passengers should be given priority, especially on public transport.

2. To ensure that users, employees and all collective, social and environmental aspects of an acceptable, safe transport environment are improved, transport safety is improved and objectives are set for this purpose.

The following measures must be taken in order to achieve the above mentioned policies:

- Development of modal transport,
- Passenger transport, development of public transport,
- Development of infrastructure,
- Development of intelligent transport systems,
- Cooperation in research and development

5. Results

This study aims to determine the current status of transport policy in Turkey in terms of traffic safety and transport policy should be to determine the probable future. This study identified transport policy in Turkey, but no studies have been done carried out. Short-term, day-to-day solutions for transportation problems have been produced. This situation enlarged the problem rather than solving it.

As a result, the share of road transportation should be reduced in freight and passenger transport. Transportation systems should be operated in such a way that they complement each other. Institutions and organizations related to transportation should work in coordination with one another.

In recent years, Turkey has made large investments particularly in terms of transport infrastructure. However, railway transportation infrastructure is strengthened and high-speed train works are being carried out. It is hoped that the above-mentioned policies will be implemented when these studies are completed.

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Research Article

Forecasting operation times by using Artificial Intelligence

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ABSTRACT

Due to increased competition, companies must reduce delivery and costs on time and provide the desired product characteristics. This study was carried out in a firm that manufactures napkin machines according to the order. The most important problem is that the suppliers cannot deliver to customers on time. For effective production planning, it is necessary to use the correct operation times for each machine used. The times were estimated by using the Artificial Neural Network (ANN) approach and the Taguchi Design of Experiment was used to estimate the optimal combination of ANN parameters. According to the results of the research, it is found that the number of layers and neurons have significant influence. By using the ANN method, the time spent in parameter design is effectively reduced and the efficiency of the algorithm is increased. Estimation performance is compared with the statistical analysis. This model proved to be statistically reliable in estimating operation times. Thus, the operators will be able to estimate the processing times for new designs.

1. Introduction

On Time delivery and selling the product with the desired characteristics is important for the customer satisfaction. And an efficient scheduling should be done by using the right data. Effective production planning is a must in order to avoid problems in the production process. For a proper production planning, it is necessary to use correct data. There are various methods for collecting data. With time study method, time of a job is recorded under certain conditions at a certain working speed. The obtained data is used to calculate the standard work time. These standard times are used in many different areas such as optimization, performance evaluation. ANN is one of the techniques widely used in the field of optimization. Various techniques are used to select appropriate levels of these parameters. Some studies are based on experimental design method or previous studies in the literature. Due to the systematic and scientific, Taguchi method which is the one of the design experiment is used. This application was implemented in a machine manufacturer. The company's biggest problem is that customers cannot make their demands on time. Company records indicate that the average delivery time of the product is 113 days. The main reason of the late delivery is that each of the machines manufactured according to the order has different characteristics and the standard times are unknown. Especially for machines with different characteristics, it is very difficult to estimate the processing times according to experience and mind. Thus, the ANN method is an appropriate tool for predicting irregular and complex systems. In this study, it was researched whether the YSA method has an appropriate modeling approach to estimate the duration of operation. Inputs of the YSA method are factors affecting the duration of operation and also the data determined by experts in the field. In order to obtain training and test data sets, both time study studies and company records were used. An ANN structure for each machine is designed and trained using more than 100 sample groups, tested using thirty-eight datasets. The Taguchi Experiment Design was used to optimize the

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parameters in the method. Hypothesis testing was used to test whether the method was reliable. Thus, the firm will be able to estimate the duration of planning activities of the new designs with the determined factors and the data collection phase, one of the largest time-consuming activities of a company, has been completed effectively. In this paper, firms can give realistic term time to their customers if they determine the factors affecting the delivery time during the workload. Estimating the realistic delivery date provides customer satisfaction. This situation provides a competitive advantage for the company and eliminates the cost penalty resulting from the incorrect deadlines. In section 2, general information about artificial neural networks is given, and ANN's evaluation methods are explained. In section 3, a model has been proposed for estimating the processing times. First, the problem was determined and performance was measured by ANN method. Experimental design method was used for optimization of parameters. Whether the results obtained are meaningful or not is tested using a hypothesis test. In the result section, the data obtained was analyzed and interpreted.

2. Artificial neural networks

Artificial Neural Networks used in classification, prediction and recognition models are a very important tool that imitates the functioning of the human brain. Multilayered MLP structure is the most widely used design in estimation. For MLP design for time series estimation, it is important to identify variables such as input neurons, hidden layer, and output neurons [1]. Artificial Neural Network method is inspired by the human brain [2]. Neuron forms a weighted sum of its inputs. Bias is added as a constant term. This sum is then passed through linear, sigmoid or hyperbolic tangent as a transfer function. Most widely used kind of neural network is Multilayer perceptron [3]. The units are organized in a way that determines the network architecture which has an input layer, one or more hidden layers and an output layer in feed forward networks. To determine the optimal network architecture, too many combinations were computed. These combinations contained transfer functions, hidden layers, units in each layer. Neural networks involve training and learning steps to forecast. Feed forward networks are carried out in a supervised manner in training step. The training set is formed by the historical data, included inputs and the related outputs, which is proffered to the network. The success of training depends on the convenient elected of inputs for neural network training. Neural network arranges an input–output matching, setting the weights and biases at each iteration to minimize error between the outputs and desired outputs in the learning step. Learning requires an optimization process which is replicated until a convenient criterion [4]. In addition, it does not require mathematical models, does not require a rule base, and has the ability to self-learn and organize [5]. ANN method is used in a wide variety of areas. It is possible to give examples such as weather forecasts [6,7,8,9], finance [10,11,12], exchange rates [13,14], energy needs and system [15,16,37], time series [17,18,19,20,21,22], recognition [23,24], cost estimation [25,33-36]. ANN and regression analysis method are used for high manganese steel tool life. The criteria's are different cutting conditions of feed rates, depth of cuts, cutting speeds, surface temperatures [26]. The disassembly time estimation method is used by providing one of several needed metrics for use during product design in this research [27]. Time estimates provide a powerful measure of ease of disassembly when used for comparing alternative designs of the same product. This paper [28] proposes a machining time estimation model using several factors. These are distribution of NC blocks, length, angle, federates, acceleration and deceleration constants, and minimum feed rate. The study estimates the processing times of the machines according to the selected criteria. We tried to end up with an intelligent system for the forecasting of drilling operation times and related subjects. It is not encountered a study on estimation of operation times in literature by ANN method.

2.1 Forecasting evaluation methods

The estimation ability of the samples is evaluated according to the mean absolute error (MAE) in the following:

$$MAE = \sum_{i=1}^{n} \left| P_i - A_i \right| / n \tag{1}$$

Where P_i and A_i are the i_{th} predicted and actual values, respectively, and n is the total number of predictions. In this study, the mean absolute error (MAE) is calculated.

3. Model for Estimation of Operation Times Using Artificial Neural Network

The study was achieved of four sections. In the first section, to obtain the input parameters of Artificial Neural Network, the reasons affecting the drilling times are determined by domain experts with brainstorming. Then the time study was conducted according to specified criteria. In the second section, for ANN parameters which are number of layer, number of neuron, learning coefficient and the coefficient optimization, L16 orthogonal array Taguchi Design of Experiment method is used. In the third stage, training and forecasting data set is determined and ANN is applied according to the level obtained at the end of the design of experiments. In the last section, showing whether the performance of the model is acceptable MAE value and hypothesis value is determined. In the Figure 1 flowchart of the model is given.

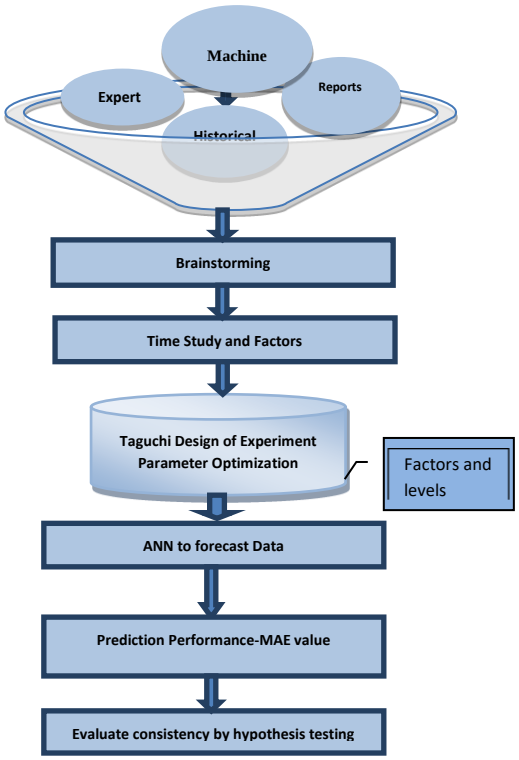

Figure 1. Flow chart of Model

3.1 Problem Definition

This research is studied in a machine production factory which has a problem about the inability of the orders on time. The inadequacy of the operation time of the required parts and the different specifications of the machines cause the delay in the production. To arrange effective timetable and to eliminate congestions, the factory needs to use the reliable operation times for each machine used in production. So in this study it is investigated whether the ANN is an appropriate modeling approach for estimating the operation times or not. For the inputs of the ANN, the factors affecting the drilling times are determined by domain experts:

Material Type: The operation times are affected by the hardness of material. In the company seven types of material is worked: St 37, St 47, S1030, S1040, S1045, S4140, and Aluminum

Dimensions of Material: The material's size big or not is effected manufacturing time

Surface Quality: Small tolerance is increased the manufacturing time. For this reason cutting velocity is fallen down. This increases the production time.

The Number of Holes to be processed: The number of hole on material is affected manufacturing time. If the number of holes is many, the manufacturing time increases.

The number of diameter changes: The holes in different sizes increase the manufacturing time.

The number of surfaces to be processed: It is necessary to know how many surfaces of the part will be processed at the machine and also the drilling lengths. If more than one surface of the part is to be processed, the part is removed from the device. This will increase the preparation time.

Complexity: The difficulty of processing the shape of the piece increases the processing time.

According to above defined factors which are material type, dimensions of material, surface quality, the number of holes to be processed, the number of diameter changes, total depth of drilled holes, the number of surfaces to be processed, complexity ; the time measurement was carried out. Number of layer, number of neuron, learning coefficient, the coefficient of momentum is used for ANN model. Selecting the proper parameters' levels will improve the performance of ANN.

3.2 Design of Experiment

Various techniques are used to select appropriate levels of these parameters. Some studies are based on experimental design method or previous studies in the literature. Due to the systematic and scientific, Taguchi method which is the one of the design experiment is used. This technique which is used properly in engineering analysis to optimize the performance characteristics within the combination of design parameters were developed by Taguchi and Konishi [29]. This technique is composed three-stages. First one is system design which includes the scientific and engineering information that is necessary for producing a part. Second one is parameter design which helps to decide and to analyze parameters about the optimum combinations. Third one is tolerance design which helps to decide and to analyze tolerances about the optimum combinations [15]. By using Taguchi method, the number of experiments which may take a long time and increase the cost, can be reduced. All parameters work with a special array to learn with a small number of experiments. Taguchi offers the use of the S/N ratio for evaluating the performance of the system. The S/N ratio approaches can be called as three types: smaller is better, nominal is best and larger is better [16, 32].

Smaller is better: In case of this case, the ideal target value is zero. S/N ratio is given below.

$$S/N\ ratio = -log(\sum Y^2 / n) \qquad (2)$$

The larger the better: This case is the opposite of the Smaller-is-Better.

$$S/N\ ratio = -10\,log[\sum(1/Y^2)/n] \qquad (3)$$

The Nominal the best: For this case, target value is the most desirable for the product means that neither the upper nor the lower value.

$$S/N\ ratio = 10\log(\overline{Y^2}/S^2) \quad (4)$$

In this study four factors were chosen and two levels were considered. So, for this research, an L16 orthogonal array was selected. Each run would have five replications and as a result, 16×5 = 80 data values were obtained. The aim of the experiment design is to determine the optimal level of artificial neural network parameters. Four factors have been identified to design the experiment. These are, Number of Layer, Number of neuron, Learning coefficient and the coefficient of momentum. For this study two levels were chosen and shown in Table 1.

Table 1 .Taguchi L16 orthogonal array

	Layer	Neuron	Learning coefficient	Momentum coefficient
1	1	1	0.2	0.6
2	3	1	0.2	0.6
3	1	3	0.2	0.6
4	3	3	0.2	0.6
5	1	1	0.4	0.6
6	3	1	0.4	0.6
7	1	3	0.4	0.6
8	3	3	0.4	0.6
9	1	1	0.2	0.8
10	3	1	0.2	0.8
11	1	3	0.2	0.8
12	3	3	0.2	0.8
13	1	1	0.4	0.8
14	3	1	0.4	0.8
15	1	3	0.4	0.8
16	3	3	0.4	0.8

To study the main objective function, the data from design of experiments were used. Smaller is better is the target function. The S/N ratios were calculated as in the case of smaller is better i.e. Eq. (2).

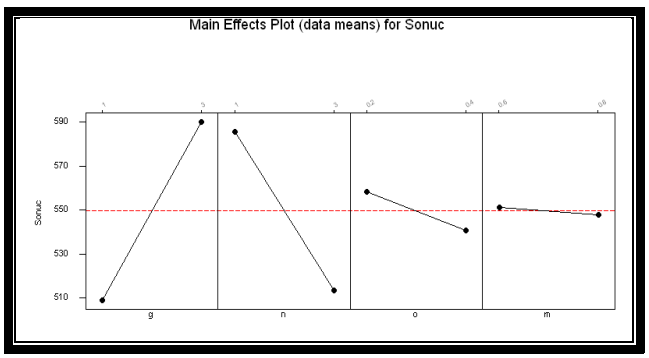

Figure 2. Main Effects of parameters for Means

Figure 2 shows the main effect graph of four selected factors for the Taguchi method and number of layer (g) and Number of neuron (n) followed Learning coefficient (o) are the major factors that affects the response. This effect can be clearly seen in Figure 2 which is resulted as having different slopes in each interval and the optimum levels were: g (number of layer: 1) n (number of layer: 3) and o (Learning coefficient: 0, 4) and m (The coefficient of momentum: 0, 8) respectively. In addition to S/N ratio analysis, main effects of the process parameters on the mean response was analyzed. For each factor the mean response referred to the average value at different levels.

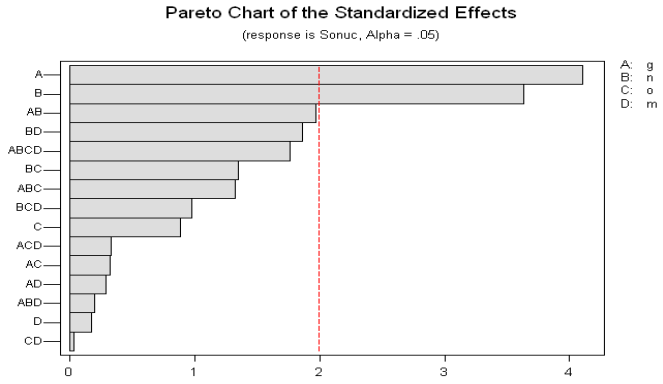

Figure 3. Pareto Chart of Effects

In each experiment, possible combinations of the levels of factors were investigated and the main effects and interactions between the factors were determined. Figure 3 shows the effect of process parameters on average S/N ratio. Thus, better results have been obtained by optimizing the ANN parameters using the Taguchi method.

2.3 ANN Method Applications

For machine, eight factors are determined as ANN inputs. According to these factors, the finished times are determined. Part of the YSA output was taken from company records and the rest was taken from the time study. MATLAB (6.5) toolbox is used for ANN. For network type feed-forward back propagation is used. 8 inputs are used. Inputs ranges are 0-1 (the finished times are normalized). TRAINGDM is used for the training function. TRAINGDM is a network function which updates weight and bias values according to gradient descent with momentum and for adaption learning function .For model learngdm and for performance function, MSE is used (It is a network performance function. It measures the network's performance according to the mean of squared errors). Furthermore absolute deviation is calculated for training and learning data. Architecture and bias weights of proposed model is shown in Figure 4.

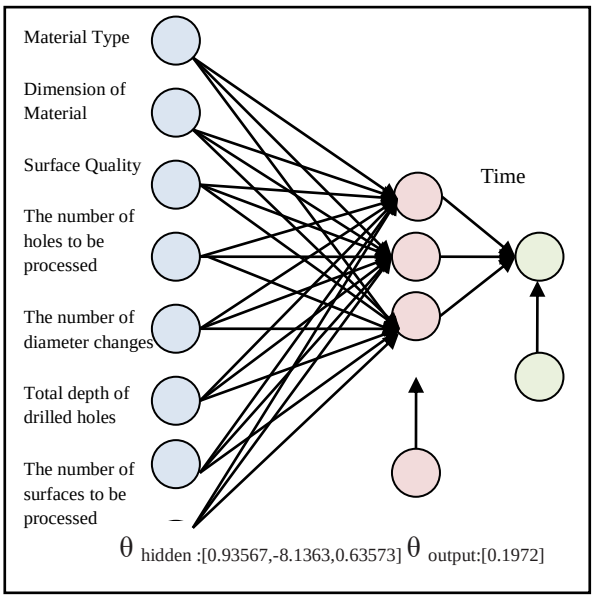

Figure 4. The Architecture and Bias Weights of Model

For hidden and output layers LOGSIGMOID (logsig (n)=1/(1+exp(-n))) (Linear Transfer Function) is used.

3.4 Performance Model

For drill machine about 70 experiments are made. To decide the best structure of the ANN model, the sensitivity of the ANN model can be tested by different neurons. It has been selected as 1, 3 and 5 in the hidden layer. This layer which contains different neuron numbers obtains the best structure of the ANN model. In the hidden layer there are three nodes and the value 0.2 for learning rate and the value 0.8 for momentum coefficients obtains the best structure of the ANN model. Data are subjected to training 1000 epoch and sum of min square error before 100 epoch constant condition and continue decreasing. For training 100 samples are used. The Result Of 1000 epoch performance, minimum square mean 0.00881626 (obtained from normalize data) After Artificial Neural Network the relationships between events are trained, ANN is forecasted manufacturing time samples which has not known before. For test data and actual data are given in Figure 5.

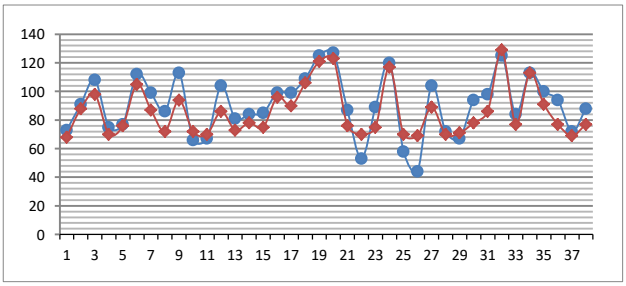

Figure 5. Comparison of Actual and ANN Simulated Data

For test data between Actual Data and Training data absolute deviation 332 minutes are calculated. This is for each manufacturing time approximate 8.74 minutes. (Obtained from ANN's mean is 86 minutes.) Obtained from ANN and actual data has to be consistent, therefore in this study two masses(ANN data and Actual data) are made a comparison and mean value between these masses must be forecasted or for this distinction hypothesis test must be done.

3.5 Hypothesis Test

To make this comparison the necessary knowledge of the each population is obtained from samples. Using sample dataset about two populations mean value is made induction. Table 2 shows H_0 and H_a hypothesis for big samples.

Table 2. Big Sample Z Test For $\mu_1 - \mu_2$

Null Hypothesis	**H_0: $\mu_1 - \mu_2$ = Hypothesis Value**
Test Statistically	$z = \dfrac{\bar{x}_1 - \bar{x}_2 - (\mu_1 - \mu_2)}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}}$
Ha: $\mu_1 - \mu_2$ > **Hypothesis Value**	if z > z critic value H_0 reject (right queue test)
Ha: $\mu_1 - \mu_2$ < **Hypothesis Value**	if -z < -z critic value H_0 ret (Left queue test)
Ha: $\mu_1 - \mu_2$ ≠ **Hypothesis Value**	if z >z critic value or –z < -z critic value H_0 reject

Comparison between the two populations' characteristics is distinguished [30, 31]. In this study μ (the mean of the population) σ (the standard deviation of the population) $\bar{x}$ (the mean of the sample) and s (standard deviation of sample) are shown in Table 3.

Table 3. Symbols of mean, variance, standard deviation

	Mean value	variance	standard deviation
Pop.1	μ_1	σ_1^2	σ_1
Pop.2	μ_2	σ_2^2	σ_2

	Sample Size	Mean value	Variance	Standard deviation
Sample 1	n_1	$\bar{X}_2$	s_1^2	s_1
Sample 2	n_2	$\bar{X}_1$	s_2^2	s_2

$$z = ((\bar{X}_1 - \bar{X}_2) - (\mu_1 - \mu_2)) / \sqrt{(s_1^2 / n_1) + (s_2^2 / n_2)}$$

$$z = ((98-86)-0) / \sqrt{(15464/38) + (10938/38)} = 0.185$$

% 95 confidence level (z=1.645) obtained from ANN dataset and actual values don t have differences. That is to say H_0 ($H_{0:}$ $\mu_1 - \mu_2$ =hypothesis value=0) null hypothesis is accepted. To conclusion there is no difference between datasets statistically.

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4. **Conclusion**

On time delivery is an increasingly important strategic factor in the area of global competition. Successful firms seek to introduce products or service early and respond to customer orders punctually. To be successful in competition, new generation firms should have flexible manufacturing, rapid response, product variety and there are too many customers types that have distinct requirements about cost, products, operation time for each product.

In order to schedule and achieve on time delivery, it is very important to forecast the operation time of parts and products in the beginning stage of the product development process. While it is easier to know the operation time for standard products, it is much more difficult to know the operation time and process when the company has a wide and diverse product range. This research is studied in a machine production factory which has a problem regarding the inability of the orders of the customers on time. The inadequacy of the operation time of the required parts and the different specifications of the machines cause the delay in the production. For preparing effective plans and to regulate the production flow of the factory needs to use accurate operation times for each machine which are used in production. This research has been carried out in a firm that cannot deliver orders to customers on time. The processing time of the machine parts is unknown and therefore the delays occurs. For effective planning and production flow, correct operation times should be used for each machine. First of all, machine factors are investigated and eight factors which are material type, dimensions of material, surface quality, the number of holes to be processed, the number of diameter changes, total depth of drilled holes, and the number of surfaces to be processed, complexity are determined. The operation times are forecasted by using ANN approach and ANN is trained by using a sample group with 100 instances and tested with 38 datasets. ANN method parameters may vary depending on different problem types. If it is desired to reach global optimum for the ANN method, it is important to select the appropriate parameters level of ANN. It also impacts the efficiency of ANN. Most users select parameters manually based on the reference values of previous examples. But this trial-and-error method is wasting time, not effective, and often it could not reach the optimal combination. Therefore, this research was studied with optimal parameters using Taguchi experimental design and parameter combination design in ANN. With respect to the research results, number of layer and neuron are the most important parameters of the ANN model. From the research results optimal parameter combination created and confirmation experiment is conducted. It can be seen that if the obtained parameter combination is strong and reliable, the results can be predicted with less error. Also, this research method, increase the algorithm's efficiency, even decrease the time that spent on parameter design using ANN. The findings gained from this study will be used for the new process designs by establishing model to calculate the operation times. Obtained from ANN's deviation dataset is tested %95 confidence level and actual dataset and obtained from ANN's dataset have no difference statistically. So the ANN approach is found to be reliable for forecasting the operation times depending on the statistical analysis. In the study, processing times were estimated for determining specific criteria. Likewise, forecasting can be done by determining the

factors affecting the operation of the different machines. Thus, when the operation time is known, better planning can be done, in areas such as capacity planning, product delivery time and the firm can estimate operation times for new design.

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Research Article

Projected potential of Landfill gas in Çukurova region

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ABSTRACT

Municipal solid waste (MSW) is increasing in parallel with population surplus. Removal of this waste is essential due to not only bad smell and image pollution but also the formation of dangerous methane gas during the disposal. Methane can be used as an energy source because of its calorific value. Waste management strategies aiming at converting domestic wastes from a threat in terms of environment, human health, and transforming wastes into an input for the economy need to be widespread in Çukurova Region. In this study, the potential of MSW in Çukurova region is presented according to the base year of 2014 data using the projection of population who are supposed to live in this region. For this evaluation, LandGEM modeling tool is used, and the projected gas generation is provided. Since there is a disposal facility established in Adana, the parameters used for modelling are different for Adana and Mersin. A bioreactor was established in Adana Metropolitan Municipality Integrated Solid Waste Disposal Facility thus wet inventory landfill type is chosen when modeling the landfill gas (LFG) generation. On the contrary, inventory conventional landfill type is chosen for Mersin. Results have shown that the electricity generation of Çukurova region could reach approximately 55 MW maximum capacity in case of using suitable disposal plants.

1. Introduction

For the time being, the basic energy requirement is met with the use of fossil fuels [1]. Fossil fuel reserves are rapidly declining, especially oil and natural gas reserves approaching to critical levels [2]. Scientists have had to accelerate the search for renewable energy sources because of rising energy demand, declining oil reserves, and accompanying climate changes, along with the rapidly growing population in recent years [3]. For using energy sources effectively scientists use some new technologies such as nanofluid [4], impinging jets [5], structured surfaces [6]. In our country, because of having limited fossil fuel reserves, 70% of energy consumption had to meet by imports [7]. From this point, it has become compulsory for our country to turn to renewable energy sources. Biomass has attracted a great interest in the world while it can be transformed into energy with variety of ways, such as transesterification, fermentation and anaerobic digestion in search of this new source [1,8,9]. Generally, it is possible to distinguish energetic cycles of biomass into two groups: biochemical and thermochemical. The biochemical cycle involves biomethane (oxygen-free digestion) and fermentation. Thermochemical cycle includes gasification, pyrolysis, esterification and direct burning.

Biomass sources can be divided into two groups

- Classical biomass (agricultural waste)
- Modern biomass (municipal solid waste) [2]

Disposal of municipal solid waste (MSW) that arises naturally as the result of our vital activities is a very important issue in terms of harm to human health and ensure maximum economic contribution [10]. In this context, energy production technologies from municipal solid waste are an issue to be emphasized strongly in the world. Rapid population growth, unplanned urbanization, living standards and the development of technology leads to the formation of very large amounts of waste all over the world [11]. If the wastes can be properly classified and numerically expressed, there is a chance of direct

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return to the economy. The classification can be made as open dumping, landfill, composting, reuse, recycling, recovery, and incineration [12].

The most commonly used method is to store the MSW in the landfills. However, eliminating solid wastes does not mean that remove MSW from the eye. It is necessary to evaluate the storage gas which may cause an explosion, poisoning by spreading to the surrounding area. Landfill gas (LFG) is generated by the decomposition of solid waste under anaerobic conditions, and can be recovered through the operation of gas collection and control systems that typically burns the methane gas. The most important feature of the storage gas is the energy content due to the methane content. There are four main ways to recover energy from the storage gas. These are direct heating, electricity generation, chemical feedstock and purification to pipeline quality. The average lower calorific value is around 19.75 MJ/m^3 [10].

In the Climate Change Action Plan of the Ministry of Environment and Urbanization, until the end of 2023, it was aimed to establish integrated solid waste disposal facilities throughout the country and to dispose of all municipal waste in these facilities [13]. Because of this utilization of MSW and LFG is an attractive subject for the scientists.

Çakır and Günerman [14] investigated the use of landfill gas as potential energy and electricity provided from municipal solid waste (domestic, industrial, medical waste and sewage sludge) stored regularly in Harmandali Solid Waste Landfill Area, within the boundaries of the contiguous area of İzmir.

Kankılıç and Topal [15] calculated a waste heat boiler and concluded that heat of waste gas should be used for the production of the electricity in energy production sectors from landfills.

Kurt and Koçer [16] determined the average dry biomass amount per year and its thermal (calorific) value for Malatya City.

Metin et al. [17] evaluated the municipal solid waste statistics and management practices including waste recovery and recycling initiatives. The results indicate that the household solid waste generation in Turkey, per capita, is around 0.6 kg/year, whereas municipal solid waste generation is close to 1 kg/year.

Turan et al. [18] stated that approximately 25 million ton of MSW are generated annually in Turkey. About 77% of the population receives MSW services. In spite of efforts to change open dumping areas into sanitary landfills and to build modern recycling and composting facilities, Turkey still has over 2000 open dumps.

There are some studies about evaluating the potential of MSW in different locations of Turkey in literature [19−23] but there is no study about potential of LFG production in Çukurova region from Municipal Solid Waste. On the other hand, this study is different from the other studies in literature by considering using two different types of biogas reactor according to given MSW values. The aim of this study is to determine the biogas potential in the Çukurova region and offering an opinion to establish new plants in the region.

The research presented in this paper mainly addresses following aspects; Section 1 describes the evaluation of biomass, disposal of MSW and how to handle it, and the state-of-the-art literature of MSW in Turkey, Section 2 depicts the status of solid waste disposal in Çukurova region, the composition of the MSW and the variation of the disposal activities year by year in the region. Also, the method of energy extraction from MSW by landfilling is introduced. This method involves a mathematical model, known as LandGEM, which estimates the LFG production for the cities based on the yearly variation of MSW data and operating parameters of landfill design. For electricity production, an analytical model is presented to estimate it from the data of LFG production and its conversion to power in a gas motor. In the rest of the paper, results and discussion are organized in Section 3 which presents the model estimations and the detailed discussion along with feature selection process. In Section 4, concluding remarks and suggestions for future directions are presented at the end of the paper.

2. MSW Data and Landfill Modeling

In Çukurova region, there is only an integrated disposal facility belonging to Adana Metropolitan Municipality. Figure 1 illustrates solid waste disposal map for Çukurova region.

Figure 2 shows the disposal methods of waste in the cities of Adana and Mersin.

The composition of the waste sent to the Adana Metropolitan Municipality Integrated Solid Waste Disposal Facility in 2013 is presented in Figure 3. The composition of the wastes is 65% kitchen wastes, 8% plastic wastes, 1.9% glass wastes, and 2.4% paper wastes. Metal derivatives are around 2.5%. Other wastes from rubber, leather, textiles, ash, stone, and soil account for about 24% of all municipal waste [13].

More than half of the household waste is stored in the Solid Waste Landfill Area operated by the Mersin Metropolitan Municipality constitutes kitchen wastes (Figure 4). The municipal waste accounts for about 12% plastic, 10% paper, and cardboard. Glass is 6% and metal derivatives are around 5%.

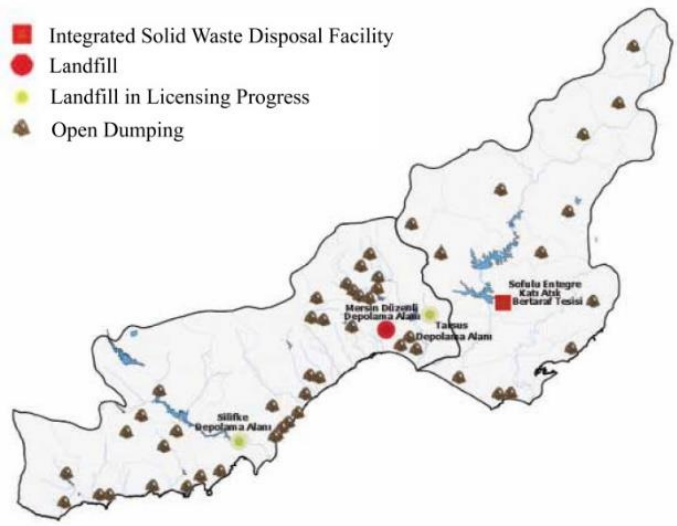

Figure 1. Çukurova region solid waste disposal map [24]

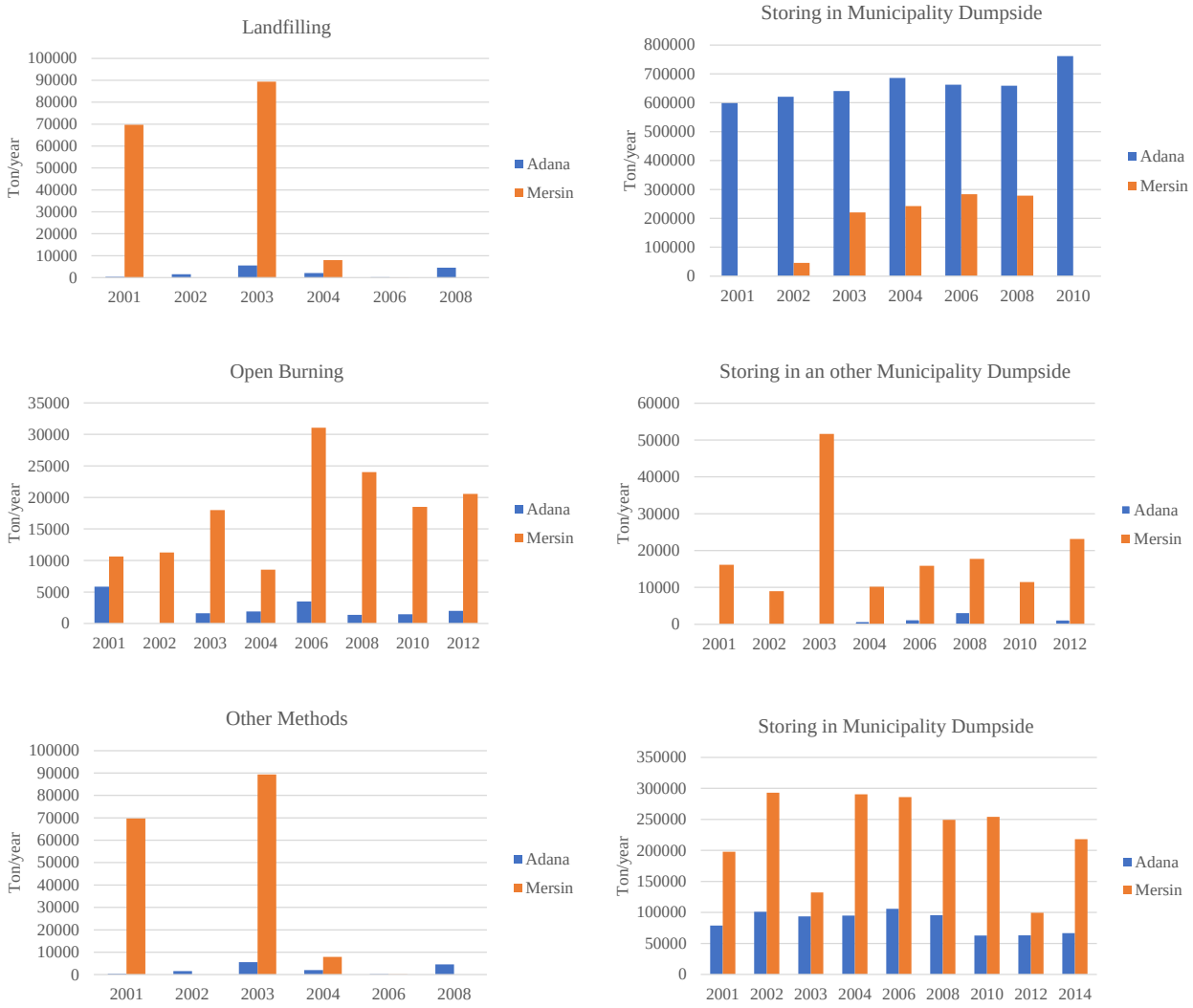

Figure 2. Disposal methods of the wastes in Adana and Mersin [24]

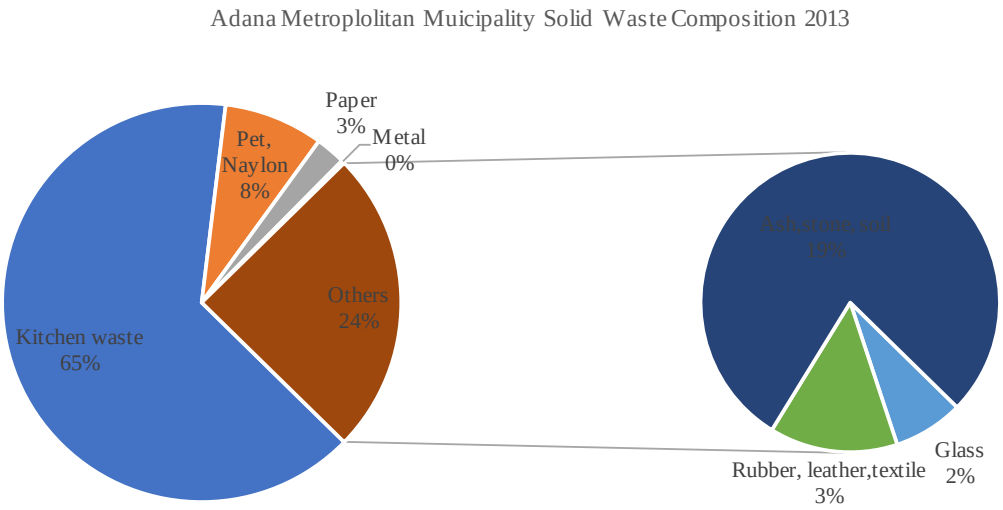

Figure 3. Adana Metropolitan Municipality Solid Waste Composition

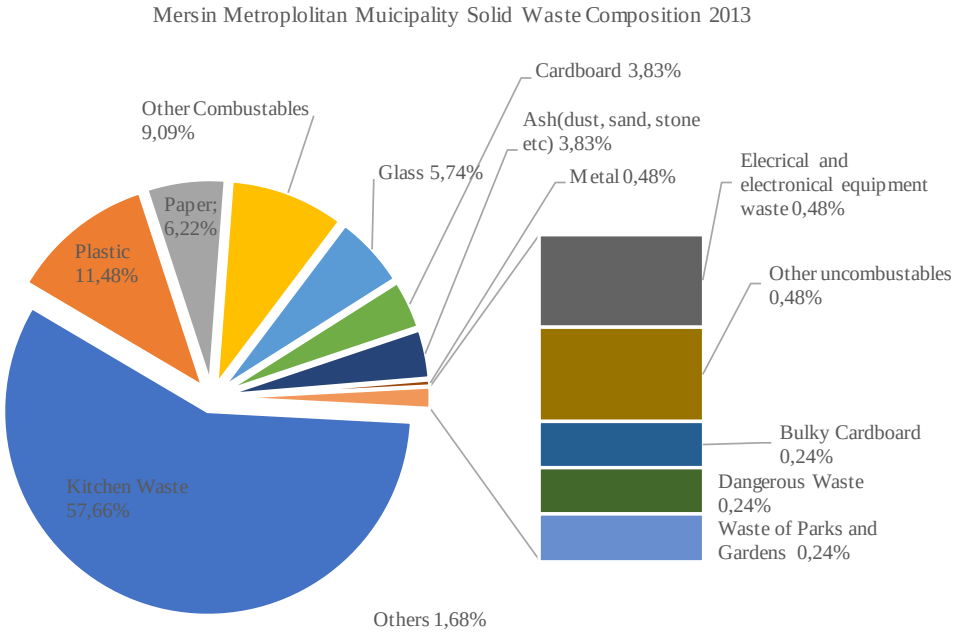

Figure 4. Mersin Metropolitan Municipality Solid Waste composition, 2013

2.1. Modeling Tool

Emissions Model (LandGEM) was used for the estimation of LFG emission rates. This study is based on the MSW data collected by Ministry of Environment and Urbanization of Turkey. Data on waste generation for 2014 were statistically made by the Turkish Statistical Institute (Turkstat) for Adana and Mersin [25].

2.2 Amount of Municipal Solid Waste

It is accepted that in this study, as the population of the necessity increases, it increases linearly in the solid waste to be disposed. For this reason, the population increase projections given by Turkstat data for the years 2013−2023 were used. The mass of waste accepted in the i^{th} year is projected according to Eq. (1):

$$M_i = M_{i-1} \frac{P_i}{P_{i-1}} \quad (1)$$

where

P_i is the estimated population at the i^{th} year,

P_{i-1} is the population of the previous year,

M_i is the estimated municipal solid waste at the i^{th} year,

M_{i-1} is the municipal solid waste of the previous year [3].

2.3 LFG emission model

The most reliable method for calculating the available LFG production is to open test wells and measure the LFG collected in these wells. But this method is expensive. The main obstacle of this method is it can be applied only if there is enough waste in the storage area

to produce LFG in large quantities. Having made realistic models solve this problem. These models typically require data such as storage time, the amount of waste stored, and the characteristics of the waste. One of these models is LandGEM which was developed by EPA [26]. The rate of formation of the CH_4 in the model is based on the first order deformation equation. The equation used in the model is as follows:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} kL_o \left(\frac{M_i}{10} \right) e^{-kt_{ij}} \quad (2)$$

where

Q_{CH4} = annual methane generation in the year of the calculation (m^3/year),

i = 1 year time increment,

n = (year of the calculation) − (initial year of waste acceptance),

j = 0.1 year time increment,

k = methane generation rate ($year^{-1}$),

L_o = potential methane generation capacity (m^3/ton),

M_i = mass of waste accepted in the i^{th} year (ton),

t_{ij} = age of the j^{th} section of waste mass M_i accepted in the i^{th} year (decimal years, e.g., 3.2 years).

The production of CO_2 is calculated from CH_4 production using the equation.

$$Q_{CO_2} = Q_{CH_4} \left[\frac{1}{P_{CH_4}/100} - 1 \right] \quad (3)$$

where P_{CH4} = methane content percentage.

Table 1 indicates parameters used for the models. LFG is assumed to include 50% CH_4 and 50% CO_2 with an additional constituent of NMOC. LandGEM considers the landfill type whether it is conventional or else arid area, on the other hand, the values of k and L_o parameters were selected considering the primary factors affecting the CH_4 generation listed in [26].

Table 1. Operating Parameters used in the model simulation

City	Landfill type	k (year $^{-1}$)	L_0 (m^3/ton)	NMOC	Methane Content (%)
Adana	Inventory Wet*	0.70	96	CAA 4.0	CAA 50
Mersin	Inventory Conventional	0.04	100	CAA 4.0	CAA 50

*Adana Sofulu Disposal Facility has bioreactor

2.4 Energy Potential of LFG

Energy Content (EC) of LFG varies by gas quality. It's typically between 16–20 MJ/m^3 for low and medium-quality LFG also can be produced by effective pretreatment to a high quality (up to 30 MJ/m^3). LFG can be converted to electricity by various techniques such as gas turbines, steam turbines and micro turbines with a conversion efficiency of 25% to 30%. Also by using reciprocating gas engines to a conversion factor, η_{ec} 28% to 40 % [27].

Gross and Net Energy Potential (GNEP) (kWh) can be calculated based on the volume of LFG collected and its energy content (Eq. 4) [27].

$$GNEP = \eta_{gc} \times EC \times G_t \quad (4)$$

Net energy potential (kWh) (NEP) derived from LFG energy recovery system can be calculated by considering capacity factor conversion efficiency for electricity generation (Eq. 5) [13].

Capacity Factor (CF) for biomass energy systems ranges in 80% to 90% [27]. Net energy potential derived from LFG can be calculated by considering capacity factor conversion efficiency for electricity generation.

$$NEP = \eta_{ec} \times GNEP \times CF \times 8760 \quad (5)$$

3. Results and Discussion

In this study, it is assumed that the landfill site began to accept municipal solid wastes in 2014. The model has calculated the closure year according to the waste acceptance capacity.

As it is seen in Figure 5, the economic feasible lifespan of LFG energy recovery Project of Adana was ended at almost 2039. On the other hand, Mersin will last at the year of 2150. Total LFG potential for this period was calculated as 1.403×10^8 m³ LFG for Adana and 7.609×10^7 m³ for Mersin. Having known that Adana has the bioreactor system in disposal facility the factor accepted as 100 (Table 2) for gas collecting system. Due to problems that might occur during gas collection of the system in Mersin, the efficiency of gas collection system was considered as 80%. It's assumed that electrical energy will be produced from LFG; thereby capacity factor for LFG to electricity is 80% and energy conversion ratio is 30%. Maximum energy potential of the site Adana was calculated as 29.8 MW. Maximum energy potential of the site Mersin was calculated as 13 MW.

Table 2. Parameters used for determination energy potential

City	η_{gc} (%)	EC (MJ/m^3)	G_t (m^3/year)	GNEP (kWh/year)	η_{ec} (%)	CF (%)	NEP (MW)
Adana	100	17.9	14.0×10^7	696.7	30	80	29.8
Mersin	80	17.9	7.6×10^7	302.7	30	80	13.0

The anaerobic fermentation system applied in the Adana Metropolitan Municipality Integrated Solid Waste Facility makes it possible to obtain methane gas and compost in the anaerobic environment through accelerating the natural decay process. Energy is generated from methane gas at the biogas plant. As of August 2013, more than 10 MW of energy is produced from the gas collected from the rehabilitated area and the gas obtained from the organic wastes. The total installed capacity of the biogas plant is 15.6 MW [10]. This result showed that Adana might need another solid waste facility since it has potential MSW to produce electricity. Currently, there is no integrated solid waste facility established in Mersin province. For this reason, a disposal facility in Mersin province has the potential to produce 13 MW of energy.

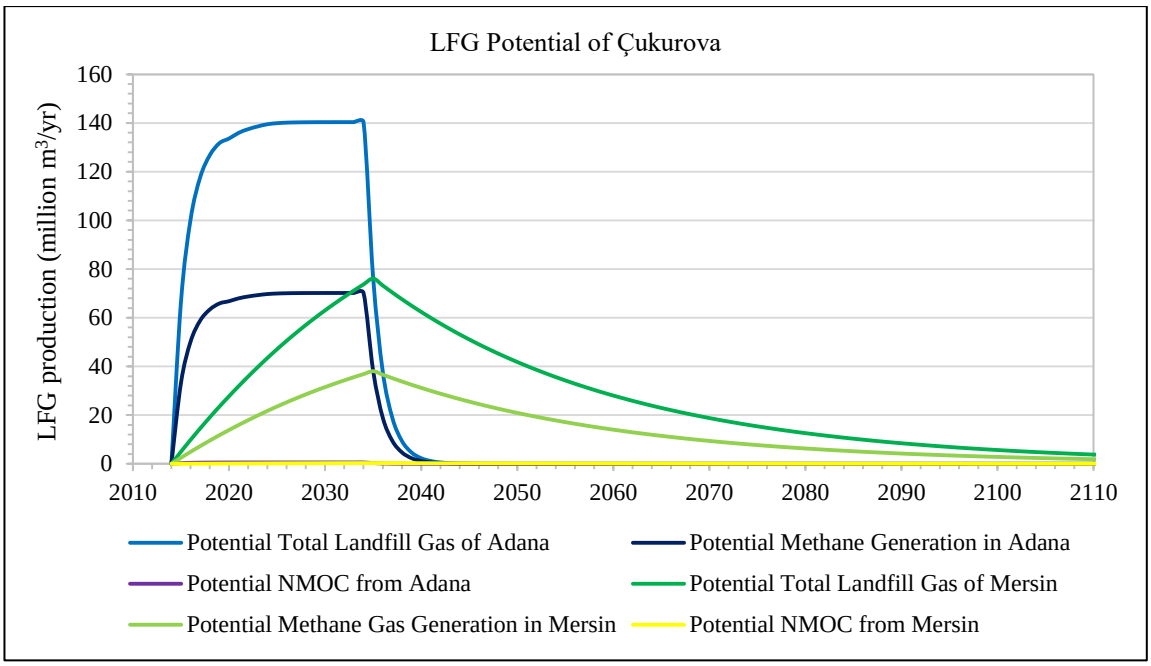

Figure 5. LFG Potential for Çukurova region

4. Conclusions

The rapid growth of the world population, changing the diversity of consumer goods and habits, has led to it to remain a serious waste problem. At the same time, research has been conducted on MSW shows that it has a significant economic value on both the national economy and human health.

The energy provided by municipal solid waste is a great prospect especially in meeting the local energy need. In terms of our developing country, getting the energy from MSW will both reduce our external dependency and create employment. Currently, there is no integrated solid waste facility established in Mersin province. For this reason, a disposal facility in Mersin province has to be established in a short time in order to gain energy from MSW.

Nomenclature

η_{ec} : Electricity conversion efficiency
η_{gc} : Gas collection efficiency
CF : Capacity Factor
EC : Energy Content
G_t : Volume of LFG (m^3)
NEP : Net energy potential (kWh)
MSW : Municipal solid waste
LFG : Landfill gas

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Research Article

An Artificial Neural Network Approach for the Prediction of Water-Based Drilling Fluid Rheological Behaviour

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ABSTRACT

It is well known that high temperatures, which change the rheological properties of the drilling fluid and can frequently cause problems in deep wells, is a major problem during drilling. The importance of the estimation and control of the rheological parameters of the drilling fluid and the hydraulics of the well increases as the depth of the well drilled is being increased to explore new oil, gas or geothermal reserves. Since it is difficult to measure these parameters with standard field and laboratory viscometers, different conventional measurements and regression-analysis techniques are routinely used to approximate the true rheological parameters. In this study, water-based drilling fluid was initially prepared and rheological properties of the fluids were measured under elevated temperatures using high temperature rheometer (Fann Model 50 SL). Then, the shear stresses of drilling fluid are predicted using artificial neural network (ANN) method depending on the elevated temperature and shear rate. The results obtained from the high temperature rheometer and artificial neural network were compared with each other and analyzed. Consequently, it is observed that the artificial neural network could be used with good engineering accuracy to directly estimate the shear stress of drilling fluids without complex procedures. The testing process shows that the average percentage error was found to be approximately 2% for the prediction of shear stress values. Hence, rheological parameters of the drilling fluid could be determined quickly and controllability was facilitated using artificial neural network structure developed.

1. Introduction

Drilling fluid, also called drilling mud, is one of the most significant components in the drilling process. Drilling fluids perform several functions including controlling formation pressures, maintaining hole integrity and stability, cooling and lubricating the drill bit and the drill string, cleaning the bottom hole, and suspending cuttings in the annulus when circulation is stopped or carrying them to the surface during drilling [1], [2]. The rheological behavior of a drilling fluid directly affects all these functions and its knowledge enables better estimation of flow regimes, frictional pressure losses, equivalent circulating density under downhole conditions, hole-cleaning efficiency, swab/surge pressures, all of which have extreme importance to improve drilling efficiency [2]. As the depth of the drilled well increases, the drilling fluid is exposed to rising temperatures. Since the temperature changes during the drilling operation, proper planning and execution of drilling, especially for high pressure high temperature wells, takes precise and correct information of the behavior of the drilling fluid shear stress. This knowledge can only be obtained by measuring the shear stress of the drilling fluid at desired temperatures in real terms. Nevertheless, this takes specific material and laboratories to measure the rheological properties of the drilling fluid. These measurements take a lot of time and should be conducted frequently to ensure the quality of the drilling fluid. On the well site during the drilling operation, there is not enough time to conduct these tests [3]. A simple, reliable, and accurate methodology for predicting shear stress for flow of water-based drilling fluid is necessary and this is the aim of this paper. Prediction of the shear stresses of the drilling mud at various temperatures provides very

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useful and practical solutions for mud and drilling engineers in planning drilling operations.

Artificial neural networks (ANNs) are information processing systems, which are trained by using existing input/output data for obtaining the relationships between has complex and nonlinear input/output relationships. In petroleum engineering applications, the popularity of the neural-network models increases for estimation and classification of the process parameters [4], [5]. The studies about the usage of ANN in petroleum engineering show that artificial neural-networks have better performance against conventional approaches in a variety of problems [5], [6], [7]. However, it is observed that there are few studies in the literature about the estimation of the rheological parameters of drilling mud by ANN. Furthermore, it is seen that the studies have been done especially in recent years. Elkatatny [3] estimated the rheological properties of KCl polymer mud by using ANN and improved empirical correlations. It was concluded that the average absolute error of the rheological parameters was less than 6 % and the correlation coefficient was estimated at 90 %. Elkatatny et al. [8] developed new empirical correlations for estimating the rheological parameters of invert emulsion based drilling fluid using ANN. The model developed determined the rheological parameters of drilling fluid with average absolute error less than 5 %. Da Silva Bispo et al. [9] developed a soft-sensor based on an ANN to prediction the apparent viscosity of the water-based drilling fluids. In a present study, an artificial neural network model was developed to estimate the shear stress of water-based drilling fluids composed of xanthan gum, carboxy methyl cellulose and bentonite. To accomplish this task, a statistical study to define the impact of the shear rate and temperature on the shear stress of drilling fluids was carried out. Apparent viscosity, plastic viscosity, yield point, flow behavior index and consistency index values, which are used to determine hole cleaning efficiency, equivalent circulation density, hydraulic calculations, and surge and swab pressure calculations, are obtained by using shear stress values. Therefore, by estimating the shear stress values, the those parameters can be calculated using the estimated results obtained.

2. Material and Method

2.1. Preparation of Drilling Fluid Samples

A water-based drilling fluid sample was prepared with xanthan gum, carboxy methyl cellulose and bentonite. Initially, bentonite was stirred with distilled water for 20 minutes, then xantam gum and carboxy methyl cellulose were added gradually and mixed for 10 minutes using five- spindle multi-mixer (model 9B) as shown in Figure 1(a). After homogenization, the bentonite dispersion was aged for 16 hours at ambient temperature conditions to ensure that the bentonite achieved the exact hydration. Table 1 shows the concentration of materials used in the formulated drilling muds and the temperature ranges studied.

Table 1. Composition of the drilling mud formulated and temperature ranges studied.

Temperature (°C)	Xantam Gum (g/350 ml H_2O)	Carboxy Methyl Cellulose (g/350 ml H_2O)	Bentonite (g/350 ml H_2O)
25	0.5	1	22.5
50	0.5	1	22.5
75	0.5	1	22.5
100	0.5	1	22.5
125	0.5	1	22.5
150	0.5	1	22.5

2.2. Determination of Rheological Properties

The rheological properties were measured using a High Temperature-High Pressure Rheometer (Fann-Model 50 SL, Houston, TX, USA) given in Figure 1(b). The equipment is a rotary viscometer and capable of measuring the shear stress depending on the shear rate over a wide range from 500 °F (260 °C) temperature to 1,000 psig (7,000 kPa) pressure. The shear stresses of the formulated mud were measured under 600, 300, 200, 100, 6 and 3 (rpm) shear rates and 25, 50, 75, 100, 125, 150 (°C) temperatures using high pressure-high temperature rheometer.

(a) (b)

Figure 1. Equipments used in the study a) Mud Mixer [10], b) Rheometer [11]

2.3. Artificial Neural Network

Artificial neural networks are computer systems that are designed to imitate the characteristics of the human

input/output of the process. The usage of ANN in engineering applications is rapidly increasing in recent years because of its processing capability when the process

brain and to automatically acquire new knowledge without any help by learning system behavior through existing data. In other words, artificial neural network systems are computer programs that mimic biological neural networks. They are able to solve problems that are too complicated for traditional techniques. Moreover, generalizations can be made in unexplored situations using familiar data through this learning ability. Therefore, artificial neural networks can be applied in many fields of our daily life such as financial issues, engineering and medical science applications and fault analysis and detection in production applications. Artificial neural network applications are generally used for prediction, classification, data association, data interpretation and data filtering [12,13]. There are basically three steps in the artificial neural network learning process; a-) to calculate the output, b-) compare outputs with target outputs and calculate the error, c-) repeat the process by changing weights. As a result of the training process, it is expected that the error calculated in artificial neural network reduces to an acceptable error rate. Artificial neural networks usually contain at least three layers such as input layer, hidden layer and output layer. All layers are composed of neurons, which are the most basic component of artificial neural networks. The input layer contains neurons that receive inputs from the outside. The output layer contains the neurons that transmit the results of the neural network. When the input and output layers are composed of a single layer, there can be more than one hidden layer between these two layers. These hidden layers contain a large number of neurons, which are all connected to other neurons in the network. In most network types, a neuron in the hidden layer only receives signals from all neurons of the previous layer. After neuron processing, it sends the output to all the neurons of the next layer. The output signal of each neuron is determined by applying activation function to its input data. The information flow takes place with the connection links from one neuron to the other neuron, and each link has a weight to create the desired input-output relationship. These weights are updated based on the error margin between the net output and the expected output [14], [15], [16].

Although there are differences in the structure of an artificial neural network and the number of neurons, there are no accepted rules for the formation of artificial neural networks. Artificial neural networks that have fewer hidden layers than the required number of layers may be inadequate for the resolution of complex functions. However, undesirable instabilities may be seen when artificial neural networks with many hidden layers are used. After the number of hidden layers is determined, the problem is how many neurons will be present in each layer. The input and output layers have specific neuron numbers depending on the number of inputs and outputs of the problem. However, there are no mathematical tests on how many neurons will be found most efficiently in the hidden layer. It should be decided by trials [13], [17].

The neural-network model was developed using 198 different experimental data sets for training, validation and testing of the network. These data sets are given in the Appendix. The network consists of two inputs and an output. The shear rate and temperature are determined as inputs and the output is shear stress. The network uses a back propagation algorithm which is the classical feed-forward artificial neural network and it uses this to calculate the error contribution of each neuron after a group of data is processed. ANN includes some parameters such as the number of hidden layers, number of neurons in each hidden layer in addition to applying different training algorithms which should be optimized in order to determine the most precise consequences. The optimal configuration of the artificial neural network is found out by a trial and error method. In this work, the number of neurons in the hidden layer is determined by an optimization procedure which minimizes some error indexes. The performance of training and testing of ANNs are appraised by the average absolute percent relative error (AAPE) and R^2, which are given as follows:

$$AAPE = \frac{1}{n}\sum_i^n \left|\frac{x - x_\mathrm{i}}{x}\right| \quad [18]$$

$$R^2 = \frac{\sum_i^n (x-\bar{x})^2 - \sum_i^n (x-x_\mathrm{i})^2}{\sum_i^n (x-\bar{x})^2} \quad [19]$$

Where n represents the number of data, x is experimental value, x_i denotes calculated value by ANN, and $\bar{x}$ is average value.

In this study, one hidden layer with twelve neurons is used in the developed network. The neuron number of hidden layers is obtained at the end of several trials to maximize the correlation coefficient R. Figure 2 shows the structure of the neural network architecture used for estimating the shear stress depending on the shear rate and temperature.

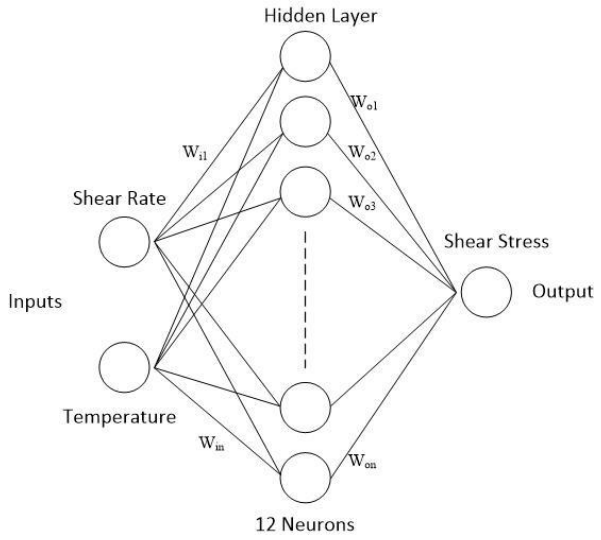

Figure 2. The structure of the Neural Network

W_{ij} and W_{oj} denote the weights of the synapse of the network. The desired input/output relationship of the network during the training process with these 198 data sets is provided by adjusting the weight of the connections. After the training process, the neural network architecture developed was tested with 20 experimental data points which were not used in the training process of the network due to validation of its estimation performance.

3. Results and Discussion

The main goal of this study is the estimation of the drilling mud shear stresses without the need for long-running experiments. For this reason a neural network architecture was developed. The performance and accuracy of the developed neural network model was checked by comparing the predicted shear stress values with actual shear stress values. The neural network was designed with ANN Toolbox of MATLAB. The efficiency of the network was evaluated using statistical parameters such as the correlation coeeficient (R) for training and mean absolute error (MAE) for testing with different data. Figure 3 shows the performance results of the ANN toolbox depending on the 198 training sets. The training, validation and testing performances were evaluated depending on the R correlation error. The large value of R means that the mean square error value of the estimator is much smaller than the average target variance and this shows that modeling of most of the variation in the input-target transformation is managed successfully by the net. In other words, the closer R is to 1.00 then the better the regression model is able to reproduce the target data.

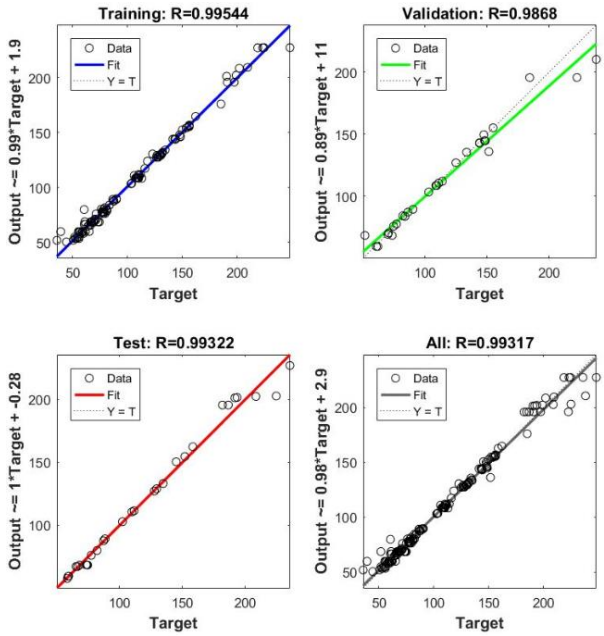

Figure 3. Results of ANN Toolbox for training, validation and test

The training data, validation data and test data sets are used for adjusting the weights of connections, validate the input-output relationship, finding the best configuration and testing the generated network to evalute the trained neural network parameters, respectively.

Neural network used about 70 % of these sets for training, 15 % for validation and 15 % for testing. The results show that the correlation coefficient value R of training, validation and testing subsets shown in the diagram is 0.99544, 0.98688, and 0.99322, respectively. The overall correlation coefficient R is 0.99317. This means that developed neural network model represents the drilling mud process for estimating the actual shear stress depending on the shear rate and temperature succesfully.

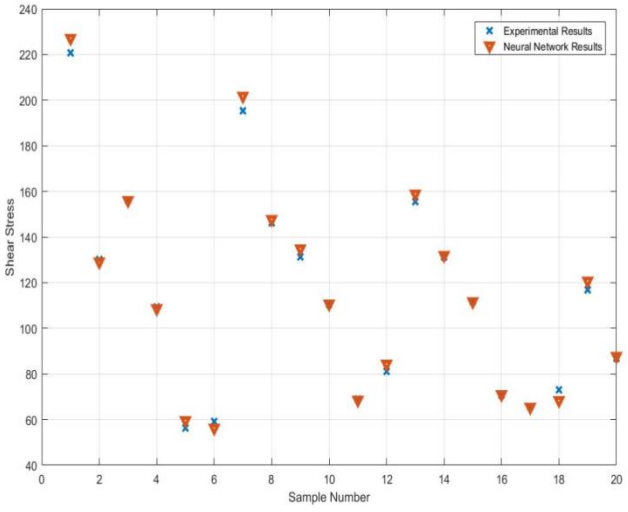

Figure 4. The predicted shear stress versus experimental values

for the testing data sets

As mentioned above, 20 different data sets were used for testing the estimation performance of the neural network architecture developed. Table 2 illustrates the results of percentage errors between values estimated by ANN and the experimental values corresponding to the inputs such as shear rate and temperature. The results show that the absolute average percentage error (AAPE) values vary between 0.0282 and 6.3330. Consequently, when the total error for estimation is calculated, the shear stress values of the drilling mud are estimated with an mean the absolute average percentage error of 2.0431 using ANN. In the previous literature, any study isnt found regarding the estimation of shear stress of drilling mud using artificial neural networks due to shear rate and temperature. However, Elkatatny [3] estimated the dial reading values with % 3.51 and % 3.27 errors at 600 and 300 (rpm), respectively. Also, Elkatatny et al [20] predicted viscometer readings with an average absolute error 3.7 and 3.48 at 600 rpm and 300 rpm, respectively. The developed neural network model illustrates that it can predict shear stress values of water-based drilling muds with high accuracy. This error performance is acceptable for the prediction of shear stress and this performance provides us with the means to reduce spending time and data collection effort since the neural network gives approximate results quickly instead of doing long-term experiments.

In order to facilitate the analysis of results, comparison between data estimated by the ANN and experimental data approach is also showed in Figure 4 clearly. The x-axis of the graph shows the number of the data sets which are given in the first column in Table 2 and y-axis denotes the shear stresses of the sample water-based mud. It can be clearly seen that the estimated and real data are very close to each other for each test data set. Nevertheless, it can be said that predicted values relatively far away from the actual values at 600 rpm comparatively to the other shear rate.

Table 2. Accuracy of ANN and correlations for shear stress—testing set

	Inputs		Output		
	Shear Rate (rpm)	Temperature (°F)	Shear Stress (dynes/cm^2)		
Number of test data sets			Experimental	Neural Network	AAPE (%)
1	600,069339	76,280001	220,711418	227,116433397176	2.902
2	199,961992	122,179997	130,139046	129,124913019282	0.7793
3	300,014671	77,9	156,09928	156,051258251427	0.0308
4	100,044328	169,340005	109,370859	108,689632943637	0.6229
5	6,089757	259,7	56,296603	59,6344213054872	5.9290
6	2,949049	304,880011	59,181073	56,3201907967738	4.8341
7	599,989346	166,820003	195,328078	201,783034843783	3.3047
8	300,054668	121,639999	146,292081	147,740418497273	0.99
9	199,95534	78,260001	131,292835	134,874179821297	2.7278
10	99,939331	78,8	110,524647	110,702923516035	0.1613
11	6,048092	78,980001	68,988273	68,5600630654917	0.6207
12	3,057378	169,520003	81,103049	84,3658863884235	4.0231
13	600,015997	256,820003	155,522386	158,881879212880	2.1601
14	299,948003	214,7	131,292835	131,990017687632	0.5310
15	199,975338	214,879997	111,678436	111,709956036522	0.0282
16	99,892672	259,879997	70,718955	71,0000093695075	0.3974
17	5,90643	215,240005	65,526908	65,4469514928737	0.1220
18	3,144874	78,980001	73,026532	68,4017784749716	6.3330
19	600,082644	302,9	116,870482	120,745531748773	3.3157
20	199,862	259,7	86,87199	87,7832372946993	1.049
				AAPE total (%)	2.0431

4. Conclusions

In this study, an alternative way to achieve reliable results for the determination of shear stress values of water-based drilling fluids was proposed because the experiments take a very long time, high effort and high cost. A neural network architecture was designed for prediction of the shear stress depending on the shear rate and temperature. A feed-forward back propagation method was used for estimation and the correlation coeffcient error performance of the network was observed depending on the training data used. The correlation coefficient of train validation and test data were approximately equal to 0.99 and as a result the overall performance of the ANN was calculated as 0.99317. After that 20 different test data were used to

test the developed neural network algorithm and the average error of test data was 2.0431 %. These results show that the developed neural network model provided very good predictions of the shear stress values. Thus, this model presents excellent performance when estimating the shear stress of drilling fluids with temperature changes under different shear rate values depending on the ranges of the training input data. This inexpensive technique, which can determine shear stress values quickly, will lead to a reduction in the total cost and time loss of the drilling operations. In addition, it will help drilling engineers to better control the drilling operation.

Nomenclature

AAPE : Absolute Average Percent Error

ANN : Artificial Neural Network

MAE : Mean Absolute Error

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Appendix

The used experimental data for training are as follows [21]

	Inputs		Output		Inputs		Output
No	Shear Rate (rpm)	Temperature (°F)	Shear Stress (dynes/cm^2)	No	Shear Rate (rpm)	Temperature (°F)	Shear Stress (dynes/cm^2)
1	599,576032	74,6600010	247,825441	101	100,012662	122,360001	109,947753
2	599,909352	74,8399990	235,710665	102	99,9693390	122,360001	109,947753
3	599,962654	75,7399990	224,172783	103	99,9076650	169,159995	108,217071
4	599,936003	75,9199990	223,018995	104	100,022661	169,159995	107,063283
5	599,962654	76,8199990	218,403842	105	100,089329	169,340005	108,793965
6	599,989346	77,1800010	218,403842	106	100,179322	169,340005	109,947753
7	599,602683	164,479997	224,749677	107	99,9660020	169,340005	109,947753

8	599,989346	165,200000	208,596643	108	100,064326	169,340005	109,370859
9	599,909352	166,279997	198,789443	109	99,7110080	214,879997	86,2950960
10	599,989346	167	193,597396	110	100,022661	215,059995	89,7564600
11	599,962654	167,720003	191,866714	111	99,9026710	215,059995	89,7564600
12	599,936003	168,259995	190,136032	112	99,7976740	215,059995	88,6026720
13	599,456001	209,659995	222,442101	113	99,8826720	215,240005	89,7564600
14	600,135987	210,920003	197,058761	114	99,9393310	215,240005	90,3333540
15	600,135987	211,820003	190,712926	115	100,029334	305,600000	59,1810730
16	599,962654	212,540005	186,674667	116	99,9776700	305,600000	59,1810730
17	599,962654	213,079997	184,367091	117	100,061000	305,600000	59,1810730
18	599,962654	213,800000	182,059514	118	99,6926780	305,600000	55,7197090
19	599,629334	254,479997	184,943985	119	100,130994	305,780011	57,4503910
20	599,762670	255,920003	161,868221	120	99,8826720	305,780011	58,6041790
21	600,362663	256,459995	158,406857	121	6,01892600	78,8	60,9117560
22	600,042648	257,540005	152,061022	122	5,78143500	78,8	51,6814500
23	600,015997	258,079997	149,753445	123	6,06142400	78,9800010	73,6034260
24	599,936003	258,800000	147,445869	124	6,03559200	78,9800010	73,6034260
25	599,709328	299,480011	151,484128	125	5,98642700	78,9800010	73,0265320
26	600,109336	301,100000	122,639423	126	5,96642800	78,9800010	66,6806970
27	599,962654	302,359995	118,024271	127	6,08475600	122,360001	71,2958490
28	600,069339	303,440005	115,716694	128	5,96892800	122,360001	74,7572140
29	599,909352	304,159995	113,986012	129	6,03559200	122,539999	77,0647900
30	599,962654	304,700000	112,832224	130	6,01475900	122,539999	77,6416840
31	300,194657	77,3600010	153,214810	131	5,90143100	122,539999	78,2185780
32	300,014671	77,5399990	154,368598	132	5,87726500	122,539999	79,3723670
33	299,961329	77,7199990	156,099280	133	5,84726600	169,340005	60,3348620
34	299,948003	77,7199990	154,945492	134	6,00809300	169,520003	80,5261550
35	299,974675	77,9	156,099280	135	5,98892700	169,520003	82,2568370
36	299,961329	78,0800010	156,099280	136	5,96892800	169,520003	81,1030490
37	300,774630	121,639999	145,138293	137	5,94476200	169,520003	78,2185780
38	300,081339	121,639999	147,445869	138	5,92143000	169,520003	75,9110020
39	300,081339	121,820003	148,022763	139	6,14475400	259,700000	59,7579680
40	299,961329	121,820003	148,022763	140	6,11058900	259,700000	58,6041790
41	300,041322	122	148,022763	141	6,07475700	259,700000	55,1428150
42	300,027997	122	148,599657	142	5,90143100	259,700000	56,8734970
43	300,547975	168,440005	141,100034	143	5,87643100	259,700000	56,8734970
44	300,041322	168,440005	142,830716	144	5,76893600	259,700000	38,9897800
45	299,988000	168,440005	143,407610	145	6,03725800	305,240005	52,2583440
46	299,848011	168,620003	143,407610	146	5,96226200	305,240005	53,4121330
47	300,014671	168,800000	143,984505	147	5,76060300	305,240005	55,7197090
48	299,888008	168,979997	143,984505	148	6,00226000	305,419989	50,5276620
49	300,014671	214,159995	129,562152	149	5,67810600	305,419989	35,5284160
50	299,948003	214,159995	130,139046	150	5,94726200	305,600000	44,1818270
51	300,014671	214,340005	131,292835	151	3,17154000	78,9800010	74,1803200
52	299,928005	214,340005	131,292835	152	3,13987400	78,9800010	74,7572140
53	299,914679	214,520003	131,292835	153	3,02071300	78,9800010	73,0265320
54	299,948003	214,700000	131,869729	154	2,97654800	78,9800010	74,1803200
55	300,307995	259,159995	102,448130	155	2,94238200	78,9800010	66,1038030
56	300,101338	259,159995	103,025024	156	2,91571700	78,9800010	68,4113790
57	300,014671	259,340005	103,601918	157	3,06154400	122,360001	78,7954720
58	299,874662	259,340005	103,601918	158	2,94488200	122,360001	78,2185780
59	300,041322	259,520003	103,025024	159	3,03904500	122,539999	77,0647900
60	299,961329	259,520003	103,601918	160	3,02071300	122,539999	77,6416840
61	200,135325	122,179997	130,139046	161	2,98571400	122,539999	77,0647900
62	200,025324	122,179997	126,677682	162	2,91321700	122,539999	76,4878960
63	200,005325	122,179997	129,562152	163	3,03154500	214,879997	68,9882730
64	199,995336	122,179997	129,562152	164	2,89405100	214,879997	66,6806970
65	199,975338	122,179997	130,139046	165	3,00988000	215,059995	65,5269080
66	199,961992	122,179997	128,985258	166	2,99154700	215,059995	66,6806970
67	200,065321	168,979997	127,831470	167	2,86571900	215,240005	61,4886500
68	200,058668	168,979997	126,100788	168	2,84905300	215,240005	60,3348620
69	200,045322	168,979997	127,831470	169	3,07987700	259,159995	64,9500140

70	200,025324	168,979997	127,254576	170	3,05571100	259,159995	64,9500140
71	199,872010	168,979997	124,947000	171	3,04654500	259,340005	62,0655440
72	200,045322	169,159995	127,831470	172	2,83572000	259,340005	61,4886500
73	199,955340	214,700000	111,678436	173	3,02987900	259,520003	59,1810730
74	200,025324	214,879997	111,678436	174	2,81655400	259,520003	55,7197090
75	200,011998	214,879997	111,678436	175	3,01987900	304,519989	61,4886500
76	199,995336	214,879997	111,678436	176	2,97321400	304,519989	60,9117560
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87	200,045322	305,600000	69,5651670	187	200,128652	78,2600010	133,600411
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89	199,842002	305,600000	68,4113790	189	199,955340	78,4399990	134,754199
90	199,828676	305,600000	70,1420610	190	99,8960080	259,700000	70,7189550
91	99,9976680	78,6199990	105,909495	191	99,9876690	259,700000	71,2958490
92	100,102665	78,8	111,101541	192	100,054327	259,879997	70,1420610
93	99,9560030	78,8	109,947753	193	6,18475300	215,240005	66,1038030
94	100,029334	78,8	110,524647	194	5,90393000	215,240005	64,9500140
95	99,8643420	78,8	110,524647	195	6,09725600	215,420003	63,7962260
96	100,007667	78,8	110,524647	196	3,12487500	169,340005	83,4106250
97	100,029334	122,179997	107,640177	197	3,01238000	169,340005	83,9875190
98	100,061000	122,360001	109,370859	198	3,04904500	169,520003	82,2568370
99	99,9243370	122,360001	109,370859				
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Research Article

Investigation of using waste banana peels in EPDM as bio-based filler

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ABSTRACT

The rubber and plastics sectors have been developing in both 19th and 20th centuries. The most of the developments have been realized in the 20th century. As a result of this, the need for petrochemical products has increased day by day. Synthetic rubber is used to protect vehicle tires, automotive parts, white goods, insulation materials and especially bridges, highways, viaducts and nuclear facilities requiring high elastic modulus from seismic and acoustical effects. Rubber type materials are preferred in many engineering applications due to due to their sufficient properties such as high elasticity. The importance of the study carried out in the rubber industry in order to improve the performance characteristics of the material as well as to increase the production efficiency and reduce the cost is increasing day by day. In order to remove or reduce the harmful effects of carbon black, which is used as a common filler the effects of additives obtained from some biological wastes such as banana peels instead of carbon black, on the physical and mechanical properties of ethylene propylene diene monomer (EPDM) rubber have been investigated. The results were evaluated considering MDR and Soxhlet extraction test results applied on rubber samples.

1. Introduction

Polymer is a macromolecule that occurs as a result of continuous repeating of small molecules. Small units that formed polymers are named as monomers. A polymer is a large molecule formed via covalent bonding of repeating monomers. Today, polymers and polymer based materials have been used in various areas such as medication, nutrition, communication, container production, clothing, buildings, highways. They are found in all materials utilized in daily life [1].

Rubber is a material that is used in many applications with increasing usage areas in our daily life. The rubbers which are seen as alternatives to metals, has many advantages because it provides ease of use in places where metals cannot be used. Rubber material can be described as a material obtained from the milk essence of some plants in natural state (latex) or synthetically obtained as a result of mixing petroleum and alcohol [2].

The Ethylene propylene diene rubber (EPDM) is an inexpensive rubber that is a widely used raw material in many areas. EPDM has been used for many years in applications such as electricity, sports equipment, footwear, industry, radiation, automobile, etc. In addition, EPDM is easy to access and resistant to aging for a long time. This makes EPDM a preferred rubber type. Low cost, good mechanical properties, good radiative protection, large filler incorporation capacity during compounding and good chemical resistance are the main reasons for the use of many areas [3,4].

The mechanical, thermal and rheological properties of EPDM can vary according to the physical and chemical properties of the content, vulcanization properties and filler. The filler is used in compounding process in different ratios in order to obtain the desired mechanical and thermal properties. In this context, the chemical interactions between EPDM and fillers and the homogeneous dispersion have a significant effect on the mechanical, thermal and rheological properties of the material matrix in the final product [2-6].

Carbon black (CB) is the most important filler for rubber and it is widely used in rubber industry due to its chemical and heat stability. In addition, carbon black is used as a colorant. Despite the use of many areas, with a long exposure, negatively affects the health of the workers in rubber industry. In addition, due to small particle size and easy static electrification, there is

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usually a tendency to agglomerate within the material and this can be a problem in some cases. In order to overcome these disadvantages, the main purpose is to use a non-harmful and environmentally compatible filler material instead of carbon black [7-9].

Although there is no study regarding the use of biofillers obtained from banana peels, many studies have been carried out for the possible use of bio-based fillers in rubber compounding. Karaağaç [10] have studied to utilize of pistachio shells as filler in natural rubber/styrene–butadiene (NR/SBR) rubber composites, characterizing mechanical, thermal, morphological properties of the composite materials. Analysis results showed that mechanical and thermal properties of final material were increased with the addition of pistachio shell. Besides, pistachio shells containing NR/SBR composites have high abrasion resistance. In addition, Botros et al. [11] have reported natural rubber (NR) containing lignin and lignin derivative material composites. Characterization results demonstrated that mechanical and thermal properties of prepared composites were improved with the addition of bio-polymeric filler material. Menon et al. [12] studied vulcanization parameters and physico-mechanical properties of natural rubber (NR) with different cashew nut shell liquid (PCNSL) content. With the increase of PCNSL addition increased of the rheological and tensile properties of NR composites. In a different study, Arayapranee et al. [13] reported NR/EPDM composites with rice husk. The addition of rice husk has decreased the optimum curing time while increasing the rheological properties. Mechanical properties have decreased with the addition of rice husk. Intiya et al. [14] reported natural rubber with filler sludge ash for the gaining an economic purpose. The pyrolysis of sludge was studied and compared with $CaCO_3$ filler. The content of sludge ash was analysed. It was concluded that both filler was activated the vulcanization reactions.

In this study, the effects of some biological wastes such as banana peels on the physical and mechanical properties of ethylene-propylene-diene monomer (EPDM) rubber were investigated. The obtained bio-based filler material was added into EPDM matrix with different ratios. MDR (Moving die rheometer), modulus of elasticity, elongation at break and swelling tests were performed to observe the effects of these wastes on EPDM rubber.

2. Material & Method

Banana peels, vinegar, EPDM rubber, mineral oil, stearic acid, zinc oxide, carbon black, TAC / 50, peroxide were used in all compound formulations.

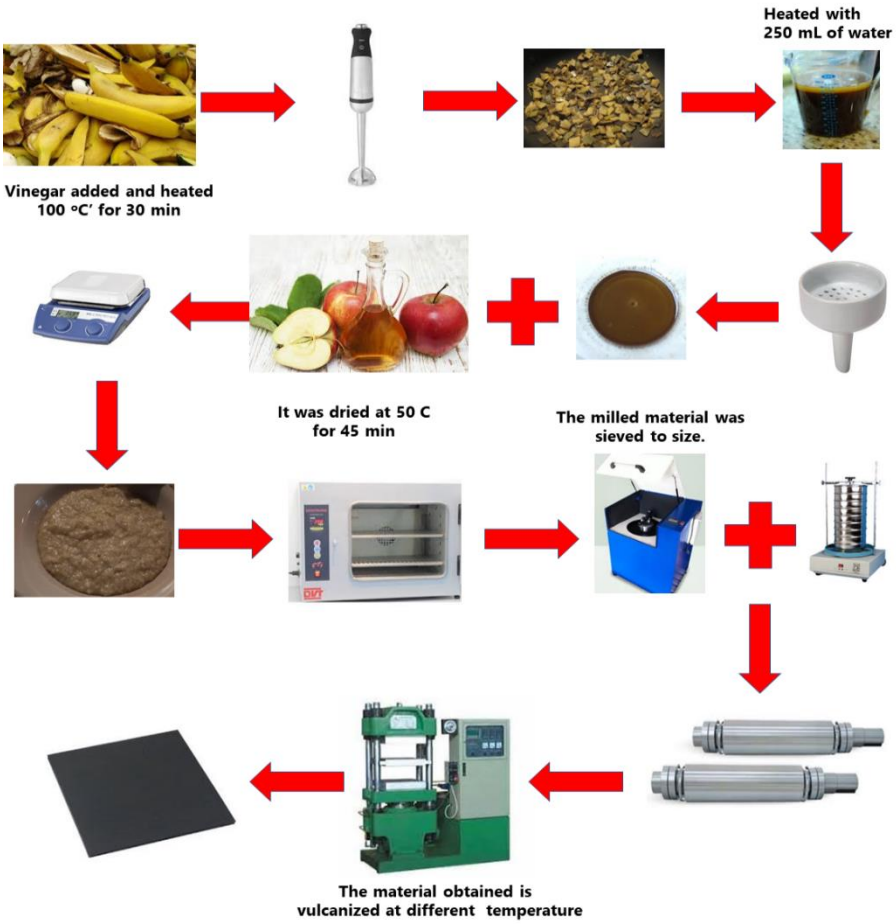

Figure 1. Schematic presentation of composite preparing

The recipes for the EPDM with different biopolymer content are given in Table 1. KELTAN 9650Q was used as the rubber matrix and purchased from Lanxess. Other ingredients in the compounds which are conventional materials (stearic acid, mineral oil, zinc oxide etc.) were used for constituting the vulcanization system. The ingredients were mixed in a Kneader-type internal mixer until they became rubber compound.

The obtained compound was taken from the mixer and peroxide was added in order to obtain crosslinking within EPDM matrix and shaped by passing it through the two roll mill. In this way, a uniform dispersion of peroxide in the rubber compound is ensured. The rubber compound is prepared to be 2 mm in thickness by a two-roll mill. 15x15 cm moulds were placed and vulcanized for 5 minutes at 172.15 ° C in a hydraulic press to have the vulcanized rubber. Schematic presentation of composite preparing is shown in Figure 1.

Table 1. Recipes of EPDM composites

Compound	Amount (phr)	Function
EPDM Rubber	100	Raw Material
Carbon Black	100	Filler Material
Mineral Oil	82	Processing aid
Zinc Oxide	5	Activator
Stearic Acid	1,5	Co-activator
TAC/50	2	Co-agent
Peroxide	7	Crosslink agent
Banana peels*	5, 7.5, 10% (w/w)	Bio-based filler material (MP)
* *Cellulose polymer obtained from waste Banana Peels*		

2.1 Obtaining Bio-Based Filler from Banana Peels

Banana peels are cut into small pieces. The small pieces of banana peel were then placed in a beaker and 250 ml of water was added and heated at 80 ° C for 5 minutes in a magnetic stirrer. When the boiling started, the heating process was terminated and 250 ml of water was added again. After the addition of water, 40 gr was weighed from the remaining precipitate by filtration and heating was continued by adding 20 ml of vinegar. After this process, the sample was taken and dried at 50 ° C for 45 minutes. After drying, the sample was milled in a ball mill. The completely powdered samples were sieved with a size of 250 µm.

2.2 Characterization

The effect of bio-based filler material on EPDM was investigated. For this purpose, Neat EPDM (Control sample) and EPDM with different bio-based filler content (5, 7.5 and 10% MP) were characterized in terms of mechanical and rheological properties.

Tensile test was performed on samples cut into 'Dogbone' according to ASTM D412 standards by applying a force of 50 mm/min in Shimadzu AGS-X Tensile Testing Machine tester. The rheological properties of the samples containing cellulose polymer obtained from waste banana peels at various content were determined by vulcanization at MDR 3000 Basic at 172,15 ° C for 5 and 10 minutes. In order to examine the MDR results, the Cure rate index formula was used.

$$CRI = 100/(t_{90} - t_{s2}) \quad (1)$$

In Equation 1, t_{90} defines the optimum vulcanization time and ts_2 defines the scorch time.

The crosslink density of composites prepared is determined by Soxhlet Extraction method as given in Equation. In the Soxhlet Extraction analysis, it is intended to dissolve the non-crosslinked moieties of the suspended materials in the solvent (hexane), measure the amount of remaining mass, and thus find the crosslinking percentage.

$$\text{Gel Content} = (W_f/W_i) * 100 \quad (2)$$

In Equation 2, W_f represents the final weight and W_i represents the initial weight.

3. Results and Discussions

3.1 MDR Test Results

The vulcanization parameters of the EPDM samples prepared using the MP at different ratios are given in Table 3 and the torque curves are demonstrated in Figure 2. As seen in Table 2, It is seen that the Neat EPDM (Control Sample) and EPDM with different MP content have similar rheological properties. When the CRI values are examined, it is once again understood that the optimum value of EPDM with 7.5 MP, which is close to each other. This result is compatible with both the mechanical analysis results and the crosslink density obtained from Soxhlet extraction.

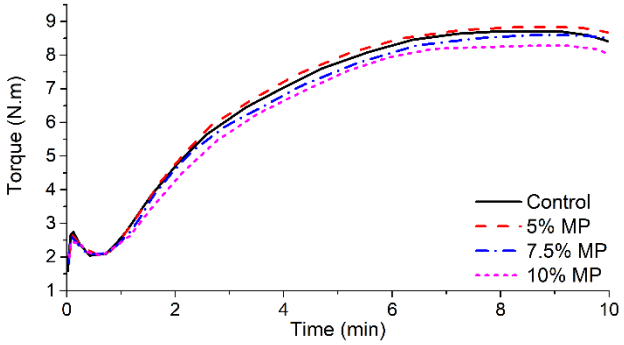

Figure 2. Torque curves of composite materials

Table 2. Vulcanization parameters of EPDM and EPDM with different MP content

Sample Name	t_{s2} (min)	t_{90} (min)	CRI
Control	1.01	7.85	14.62
5% MP	1.06	7.98	14.45
7.5% MP	1.11	7.88	14.77
10% MP	1.06	8.25	13.91

3.2. Soxhlet Analysis Result

Gel content of the Neat EPDM (Control Sample) and EPDM with different bio-based filler content is given in Table 3. It is observed that the cellulose polymer obtained from the banana peels (MP) slightly contributed the crosslinking in the EPDM composites. It has been understood that when the MP ratio exceeds 7.5%, it affects the gel content negatively. According to the obtained results of the Soxhlet Extraction, it is considered that this could be possible of the decrease of the interaction between the surfaces.

Table 3. Soxhlet extraction results

Compound	Gel Content (%)
Control Sample	79.21
5% MP	79.14
7.5% MP	80.26
10% MP	78.89

3.3 Mechanical Analysis Results

Mechanical test results of samples are given in Figure 3. When the modulus of elasticity analysis result was examined, the modulus of elasticity values increased as the MP addition increased. However, modulus of elasticity value was decreased for 10% MP case. As a result, it was understood that the biopolymer used was compatible with the EPDM matrix and increased the modulus of elasticity values.

When the elongation at break is taken into account, the best result is for EPDM with 5% MP (approx. 450%). The second best result is EPDM with 7.5% MP. When both analysis results were examined, it was selected that the optimum bio-based filler content was EPDM sample containing 7.5 MP according to tensile test results.

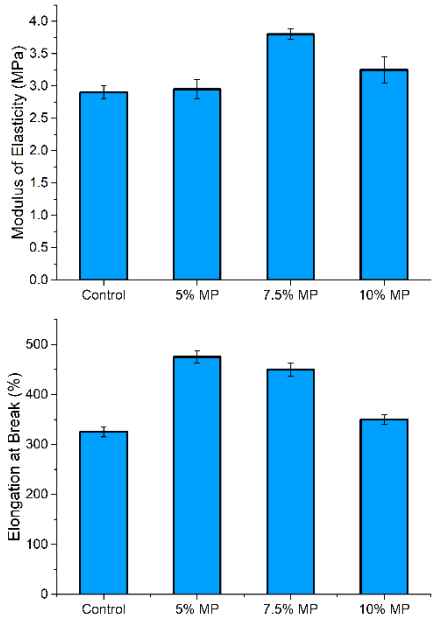

Figure 3. Mechanical properties of the samples

3.4 Investigation of the Use of Cellulose Polymer Produced from Waste Banana Peels as a Filler Material Instead of Carbon Black

In this part of the work the availability of cellulose polymer produced from banana peels instead of carbon black material with cancerogenic effects has been examined and analyses results are given Figure 4 and Table 4. During the study, the amount of carbon black used was 30 phr as given in Table 1. At this stage, MP was gradually added to the EPDM instead of carbon black as the total amount of filler material was 30 phr. When Figure 4 and Table 4 are taken into consideration, it is seen that the vulcanization parameters of EPDM containing MP composites give close results with the control sample. As the amount of added MP increases, the value of t_{90} decreases but the value of t_{s2} increases, which is a desirable result. In addition, CRI results also a similar trend. For this reason, EPDM rubber with 20 phr CB + 10 phr MP was selected as the optimum compound according to high CRI value and smaller t_{90} value compared with control sample. In the light of these results, it is understood that MP could be used instead of carbon black.

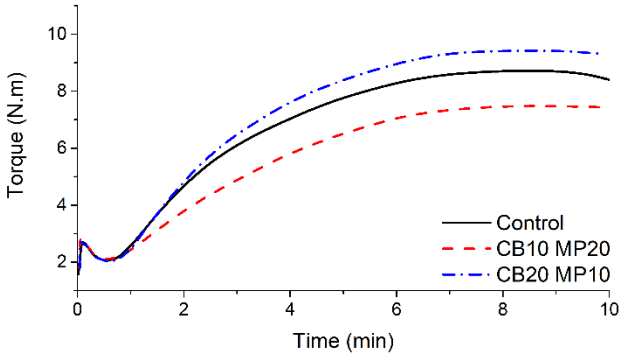

Figure 4. Effect of carbon black change on EPDM torque curves

Table 4. Effect of carbon black change on rheological properties

Sample	t_{s2} (min)	t_{90} (min)	CRI
Control Sample	1.01	7.85	14.62
CB20 MP10	1.03	7.42	15.65
CB10 MP20	1.08	8.03	14.39

3. Conclusions

In this study, the waste banana peel was used for the disposal of wastes as well as for reducing the carbon content in EPDM rubber. Firstly, the biopolymer was synthesized from banana peel wastes and then synthesized biopolymer as a filler material was added EPDM rubber at different ratios. Mechanical, chemical and rheological properties of Neat EPDM and EPDM with different biopolymer filler content were investigated and optimum parameters were chosen. Mechanical tests

results showed that with the increase of biopolymer content was increased the mechanical properties of the final material. Additionally, Soxhlet extraction test result indicated that the crosslink density of the samples containing MP up to 7.5% was increased while the crosslink density after 7.5% was decreased, which this result is compatible with mechanical analysis. In the MDR results, the rheological properties were improved by the addition of the polymer obtained from the banana shell. Furthermore, MDR analysis results showed that EPDM samples with 7.5% MP content are selected the optimum composite material owing to has higher CRI and t_{s2} value and smaller t_{90} values. It was understood that the biopolymer obtained from the banana peels could be used instead of the carbon black within the EPDM rubber and thus, the negative effect of carbon black on human health will be reduced. Consequently, it was concluded that the biopolymer obtained from banana peels is an effective filler material along with bio-based, biodegradable and environmental friendliness.

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Abbreviations

MP : Cellulose polymer derived from banana peel

CB : Carbon Black

phr : Parts per Hundred Rubber

CRI : Cure Rate Index

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Research Article

Investigation of using shelf-life passed milk in EPDM as bio-based filler

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ABSTRACT

Waste management of dairy products is an important topic for both economic and environmental aspects. In order to remove or reduce the harmful effects of carbon black used as a filler material, the effects of polymers obtained by using some biological wastes such as shelf-life passed milk instead of carbon black on the physical and mechanical properties of ethylene propylene diene monomer (EPDM) rubber have been investigated. Moving Die Rheometer and Soxhlet extraction tests were applied to the obtained compound and the results were evaluated. MDR test results showed that the scorch time of the samples increased by 10% SP filler, and Soxhlet test results were in line with MDR test. Mechanical analysis showed that the addition of casein polymer improved the elongation at break values of the samples. The tests were concluded that the best resulting sample is 10% SP. FTIR result shows that the casein polymer is chemically bonded to the EPDM rubber. The results showed that the prepared bio-based filler could be used as an alternative and non-hazardous filler.

1. Introduction

Ethylene propylene diene rubber (EPDM) is one of the most widely used synthetic rubber types containing ethylene, propylene and diene monomer. EPDM have been used for many years for the applications of rubber ignition switches, underfloor heating, electromagnetic noise protection, electronic and electrical applications wire, sports equipment, outdoor electrical insulators [1]. The diene part of EPDM shows excellent resistance to thermal and electrical properties. Low price, good mechanical properties, good radiative protection, high filler capacity and chemical resistance are the main reasons for the use of EPDM in many areas [2, 3].

The mechanical, thermal and rheological properties of EPDM can be changed by the molecular weight of the rubber and the filler used. Filling material is used in vulcanization process for rubbers in order to obtain the desired mechanical and thermal properties [4]. In this context, the chemical interactions between the EPDM and the filler materials and the homogeneous dispersion of the filler material in the polymer matrix have a significant effect on the ultimate mechanical, thermal and rheological properties of the material matrix [5, 6].

Carbon black (CB) is the most important filler material for rubber and is widely used. It is also used as a colouring agent in the rubber industry due to its chemical and thermal stability [7]. Despite the use of many areas, long term exposure to carbon black is extremely harmful to the health of workers in the rubber industry. In addition, the carbon black used often has a tendency to clump in the material, and agglomeration is often problematic in terms of material [8]. To overcome these disadvantages is to increase the production of biodegradable and biodegradable polymer composites. In addition, the use of biodegradable and biodegradable polymeric materials as a filler material may potentially reduce dependence on fossil fuel products. It is important to note that producers always look for cheaper alternatives that do not reduce mechanical and other properties [9, 10].

In the world, economic development and transformation in recent years has also affected production, consumption and trade of milk and dairy products. Especially in developing countries, per capita income and the increase in population have increased the consumption of milk and dairy products, which is a compulsory food item and occupies an important place in human nutrition [11]. This increase in demand for milk and milk products has also

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led to an increase in the production and trade of milk and dairy products and has contributed to the transformation of the dairy and dairy sector into a market that attracts national and international investments, especially in developing countries. The production / consumption of milk and milk products in our country also shows a rapid increase [12]. Parallel to this development, the amount of milk that has shelf-life passed milk is increasing day by day. Milk and dairy products that shelf-life passed are used and assessed in many milk powder, cheese, yeast, paint, glue and etc. areas [13].

There is no study regarding the usage of biobased filler obtained from shelf-life passed milk, but in the literature, there is a growing interest to use biobased fillers in different polymers and rubbers. Barczewski et al. [14] studied chestnut shell waste within poly(lactic acid). The modulus values of the sample were significantly increased with the addition of chestnut shell. Unfortunately, mechanical properties of the samples were decreased with the addition of bio-filler. Patil et al. [15] reported fly ash within chitosan composites for the purpose of filler in matrixes. The fly ash wastes were modified with a non-ionic surfactant and the final material were obtained with smooth surface and spherical shape. The addition of fly ash wastes was increased the mechanical properties. Sareena et al. [16] worked on peanut shell powder as a bio-based filler in natural rubber. The addition of the filler has increased the mechanical properties regarding to pristine natural rubber, the morphological analysis showed that the 10 phr loading was the best resulting sample. Li et al. [17] studied the examination of the effects of altering the properties of rice bran carbon (RBC) within nitrile rubber (NBR). The addition of RBC has improved the mechanical properties of composites.

In this study, the effect of the casein polymer obtained from the shelf-life passed milk on the physical and mechanical properties of ethylene-propylene-diene ter monomer (EPDM) rubber was investigated. Characterization tests such as MDR (Moving die rheometer), elastic modulus, elongation at break and cross-link density were performed to observe the effects of the bio-filler material used on the EPDM rubber at different percentages and to observe the effects of these bio-based polymeric materials on the EPDM rubber.

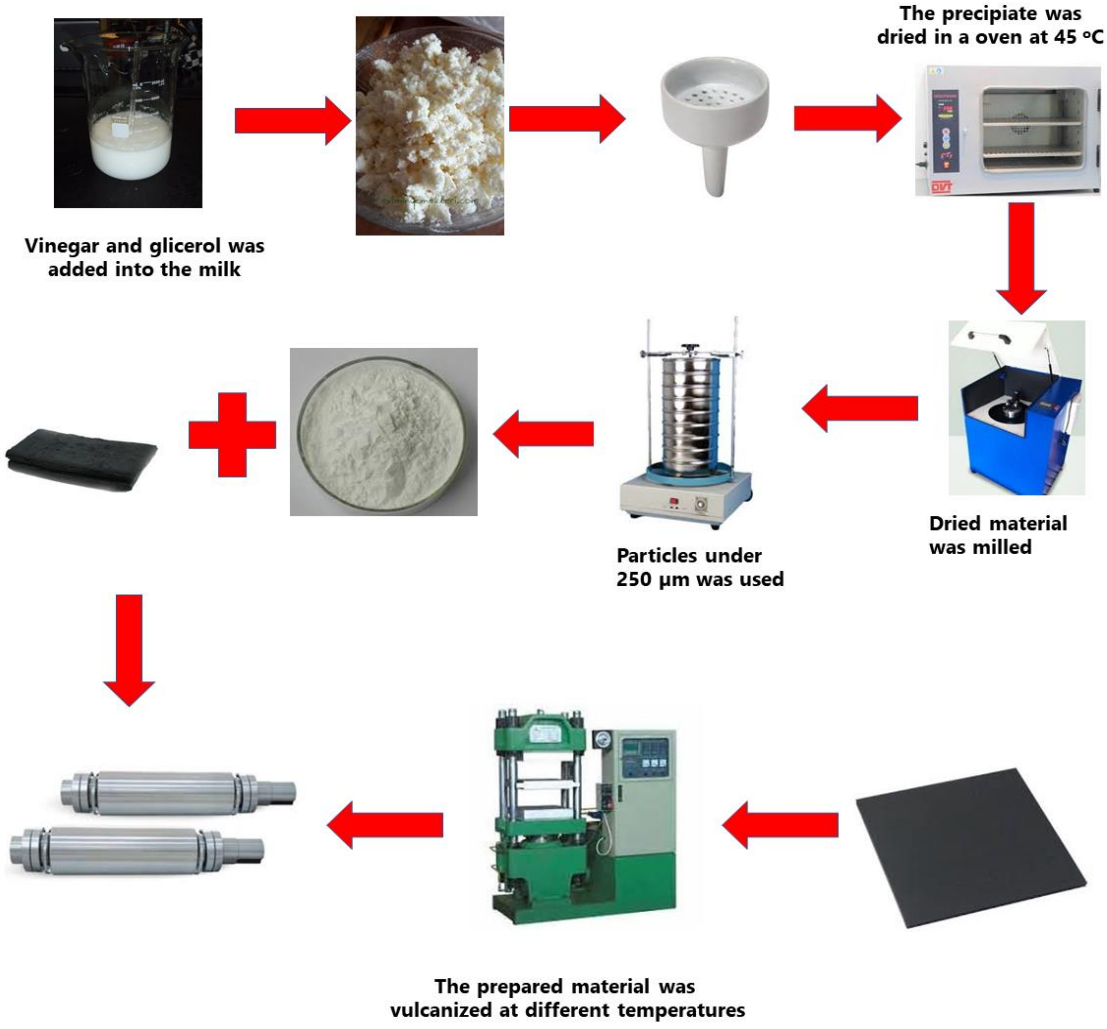

Figure 1. Schematic Representation of Sample Preparing

2. Material & Method

TAC / 50, peroxide, casein polymer obtained from shelf-life passed milk (biologically based polymeric filler), glycerine (cross-linker in casein polymerization), vinegar, EPDM rubber, mineral oil, stearic acid, zinc oxide and carbon black were used in the study.

The materials were taken in the amounts indicated in Table 1 and mixed in a Kneader-type closed mixer (Baihong mark ML-132 model) until they became mixed and rubber mixing was obtained. The mixing was taken from the internal mixer. The prepared mixing was shaped through a two-roll mill (Baihong mark HL-66 model) to obtained a 2 mm-thick EPDM sheet. The prepared EPDM sheet was placed in 15x15 mm mould and vulcanized at 172,15 ° C, 20 MPa pressure and 5 minutes in a laboratory type heat press.

Table 1. The formulate of the rubber mixing

Materials	Amount (phr)
EPDM Rubber	100
Carbon Black	100
Mineral Oil	82
Zinc Oxide	5
Stearic Acid	1,5
TAC/50	2
Peroxide	7
Casein Polymer (SP)	5, 10, 15 % (w/w)

2.1 Obtaining Casein Containing Biopolymeric Material from Complete Shelf Life

500 mL milk was added to the beaker and heated to boiling on a magnetic stirrer. After it was boiled, 125 mL Tariş mark vinegar (5-6 % acetic acid v/v) was added to the milk and glycerine (as crosslinker) was added in different amounts. Sometime later, the milk started to viscose and precipitate. The resulting precipitate was filtered using a Buchner funnel. The filtered precipitate was dried for 45 minutes at 50 ºC and the dried sample was ground to a ball mill. The bio polymeric material, whose particle size has been reduced and homogenized, has been added into the rubber at certain ratios. The schematic representation of the sample preparing is given in Figure 1.

2.2 Tests and Analyses Applied to the Samples

Various characterization studies have been carried out to test the mechanical, rheological and chemical properties of EPDM. For the characterization studies, the Perkin Elmer ATR-FTIR device was used to investigate the chemical altering of the samples. The MDR type rheometer (Montech mark MDR 2000) was used to understand the vulcanization kinetics of the process. The Soxhlet extraction was used for the determination of the cross-linking ratio and after the addition of the bio polymeric material.

Tensile breaking test was performed on specimens cut into 'Dogbone' according to ASTM D412 standards by applying a force of 50 mm per minute in Shimadzu AGS-X Tensile Testing Machine tester. Samples taken from rubber compound containing biopolymeric material at various ratios were vulcanized for 5 and 10 minutes at 172,15 ° C in the MDR 3000 Basic to determine their rheological properties. The Cure Rate Index (CRI) formula [18] was used to examine the MDR results in Equation 1.

$$CRI = 100/(t_{90} - t_{s2}) \quad (1)$$

Where t_{90}; represents the optimum vulcanization time, and t_{s2} represents the scorch time of the material.

In the Soxhlet Extraction analysis, it is intended to dissolve the non-cross-linked portions of the suspended materials in the solvent (hexane), measure the amount of remaining mass, and thus find the cross-linking percentage. In this direction, certain weighted materials were applied on a Soxhlet extraction for 24 hours. Crosslink ratio [19] of the samples was calculated in Equation 2.

$$\text{Crosslink Ratio} = W_f/W_i * 100 \quad (2)$$

Where, W_f; represents the final weight, W_i represents the initial weight.

3. Results

3.1 Effect of Crosslinker Quantity on Vulcanization Parameters

Glycerine was used as a cross-linking agent in the synthesis of shelf-life passed milk to casein polymer. Prior to casein synthesis, different amounts of glycerine were used to optimize the amount of cross linker to be used and polymerization was carried out. The synthesized bio polymeric material was added into the EPDM to study the effect of the amount of cross linker on the vulcanization parameters and the torque curves are plotted in Figure 2. Also, the vulcanization parameters are given in Table 2. According to the results of MDR analysis, t90 values were not affected by the glycerol amount added for the polymerization process, while an increase in ts2 was observed in proportion to the amount of glycerine added. From the results obtained, the optimum amount of cross-linker in shelf-life passed milk to casein polymerization was found to be 0.5 mL glycerin, and in the subsequent runs biopolymeric material produced with 0.5 mL glycerine was used for the remaining studies.

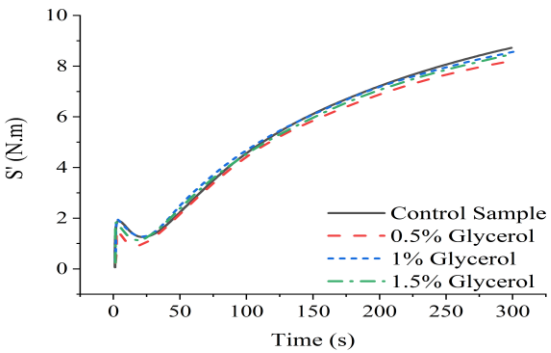

Figure 2. MDR results of bio polymeric materials produced with different cross linker quantities

Table 2. Effect of Cross-linker ratios on parameters

Sample	t_{s2} (min)	t_{90} (min)	CRI
SP (0.5 mL)	0.58	3.54	33.67
SP (1.0 mL)	0.59	3.58	33.44
SP (1.5 mL)	1.01	3.59	28.13
Control	1.05	4.00	33.89

3.2. Mechanical Test Results

The mechanical test results of the EPDM samples with different amounts of casein polymer are shown in Figure 3. When the graph showing the elastic modulus values was examined, the highest elastic modulus value was observed in the EPDM rubber (control sample) without casein polymer (SP) obtained from the milk. The elastic modulus values of SP-containing specimens as well as the Neat EPDM sample give very close results. For further analysis, EPDM rubber with 20% SP was prepared but the polymer was not homogeneously mixed with the EPDM paste. That is, the EPDM rubber has become overwhelmingly saturated with the casein polymer and a certain amount of polymer dumps into the surface of the samples prepared. For this reason, 20% SP containing EPDM rubber analysis were not applied.

In the graph showing elongation values, it was determined that the optimum composition is EPDM containing 10% SP. A reduction in the amount of elongation is observed in the EPDM pulps with a weight percentage of 10% SP. This may be thought to be due to increased surface interaction between the casein polymer produced from the shelf-life milk and the EPDM rubber.

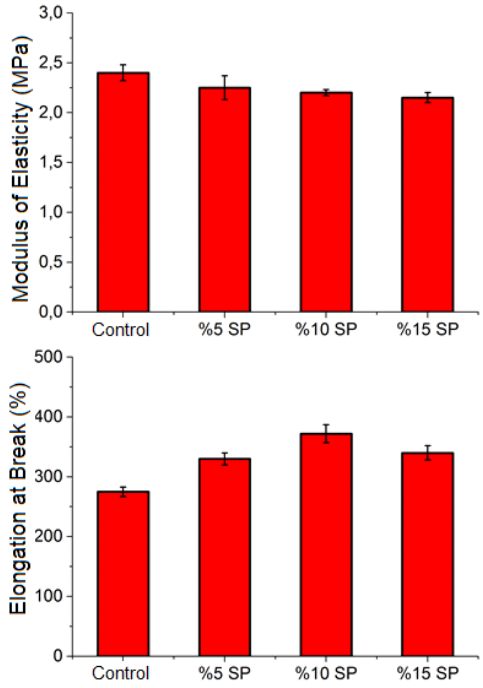

Figure 3. Mechanical test results of samples

3.3 MDR Results

The vulcanisation parameters of the EPDM samples prepared using the SP in the proportions are given in Table 3 and the torque curves in Figure 4. As can be seen from Table 3, it is seen that EPDM mixtures (control sample) with t_{90} and t_{s2} values and EPDM mixtures containing 5% and 10% SP give similar results and in this context, the CRI values are very close to each other. However, when the SP rate is increased to 15%, it is seen that the mentioned values have decreased remarkably. This resulted in a significant reduction in the CRI value of the sample containing 15% SP, which is in agreement with the results of the mechanical test.

The findings were parallel to the mechanical results of the materials for all samples. As a result, an EPDM sample containing 10% SP was selected as the optimum additive ratio based on both the mechanical data and the vulcanization parameters.

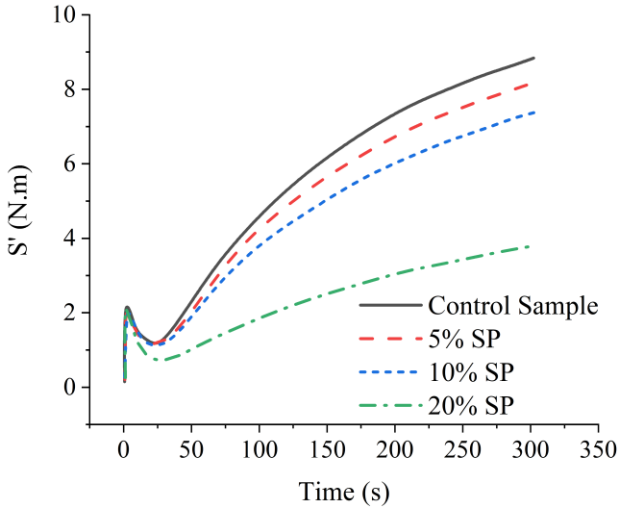

Figure 4. Comparison of MDR test results for different compounds

Table 3. Comparison of MDR test results for different compositions

Sample	t_{s2} (min)	t_{90} (min)	CRI
Control	1.05	4.00	33.89
% 5 SP	1.08	4.02	34.01
% 10 SP	1.14	4.03	34.60
% 20 SP	2.53	7.24	21.23

3.4. Soxhlet Test Results

The addition effect of casein polymer obtained from the shelf-life passed milk is shown in Table 4, which contributes very little to the formation of cross-linking in the added EPDM rubber matrix. When the amount of SP added to the EPDM rubber had a composition of more than 10%, a decrease in cross-linking was observed as a result of the analysis carried out. For the case of samples containing over SP of 10%, the migration started to take

place. The highest crosslinking ratio was calculated as EPDM with 10% SP. The findings are consistent with both mechanical and rheological test results.

Table 4. Cross-linking ratios

Sample	Crosslinking Ratio(%)
Control	76.56 ± 0.08
% 5 SP + EPDM	77.75 ± 0.12
% 10 SP + EPDM	80.23 ± 0.05
% 15 SP + EPDM	75.69 ± 0.15

3.5. FTIR analysis

The Neat EPDM has not got a molecular structure (C = O). However, in the FTIR analysis, which is given in Figure 5, of EPDM rubber containing 10% SP, a peak at 1745 cm^{-1} wavelength that represent the characteristic peak of casein polymer is observed [18]. This result shows that the casein polymer is chemically bonded to the EPDM rubber.

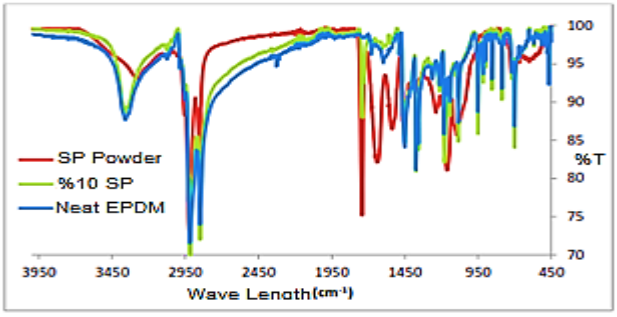

Figure 5. FTIR analysis results

3.5. Replacing Carbon Black with Casein Polymer

In the previous stages of the study, the amount of carbon black in the produced EPDM samples was 30 phr according to the formulation given in Table 1. However, in this section, the amount of carbon used reduced as 30 phr to reduce the effect of carbonaceous filler, which is carcinogenic and harmful to health, is gradually reduced with casein biopolymer obtained from shelf-life passed milk and EPDM samples is prepared accordingly. The torque curves of the prepared EPDM samples are shown in Figure 6 and the vulcanization parameters are shown in Table 5. When Figure 6 is examined, the casein polymer obtained from the shelf-life passed milk is mixed in EPDM rubber at different ratios, the maximum and minimum torque values are decreased according to the control sample of the material. Considering the CRI values, it is seen in Table 5 and Figure 6 that close results are obtained with the control sample and that the EPDM rubber with 20 phr carbon black + 10 phr SP gives similar results to the control sample. It was observed that the increase of SP amount increased the t_{90} value, whereas, the value of t_{S2} seems to be extended as an undesirable result. For this reason, EPDM rubber with 20 phr carbon black + 10 phr SP was chosen as the optimum compound.

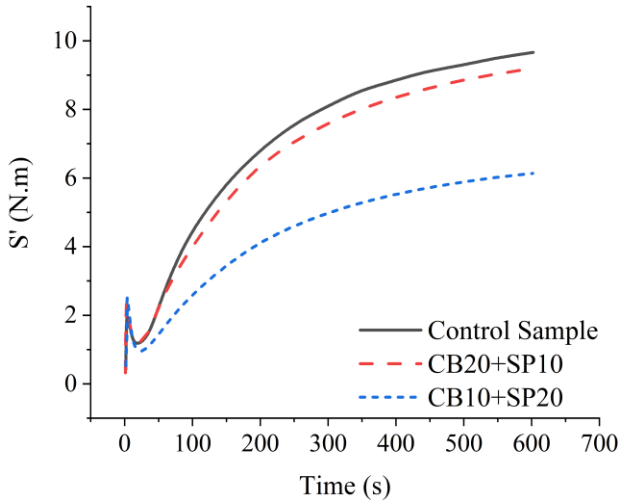

Figure 6. Examination of carbon in-effect by MDR test

Table 5. Comparison of the carbon effect

Sample	t_{s2}(min)	t_{90}(min)	CRI
CB10+SP20	0.74	3.50	36.24
CB20+SP10	0.54	3.22	37.30
Control	1.05	4.00	33.89

4. Suggestions and Discussion

In this study, casein polymer obtained from shelf-life passed milk was used for the disposal of waste as well as for reducing the carbon content in EPDM rubber. First, the casein polymer is synthesized from shelf-life passed milk and the mechanical, chemical and vulcanization properties of the final material obtained by adding EPDM rubber to certain ratios have been investigated. Analysis by mechanical tests and Soxhlet extraction showed that the addition of polymer obtained from the shelf-life passed milk increased the strength of the EPDM rubber. The results showed that the most suitable composition is the EPDM containing 10% SP. In the MDR analysis, the rheological properties were improved by the addition of the polymer obtained from the shelf-life passed milk. It has been determined that the obtained polymer can be used as a filler material in EPDM rubber and as a result of the analysis made, it is understood that polymers that made by shelf-life passed milk can be used instead of carbon black fill in EPDM rubber and it can reduce harmful effects to health of people and the environment.

Nomenclature

SP : Casein polymer obtained from shelf life finished milk

CB : Carbon Black

phr : Per Hundred Rubber

CRI : Cure Rate Index

EPDM : Ethylene propylene diene rubber

MDR : Moving Die Rheometer

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Research Article

Dosimetric Fricke Gel Systems Improved with $CaCl_2$ and Gluconic Acid

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ABSTRACT

Today, cancer is an increasingly important health problem that comes immediately after heart and vascular diseases as a cause of death. In this study primary objective is to generate an alternative to dosimetry systems that are not practical and cost effective due to increasingly complex external beam radiotherapy techniques. For this purpose, $CaCl_2$ or Gluconic acid added dosimetric Fricke gel compounds were improved to mimic human tissues by means of interaction with X- rays. The MR intensity values were linearly changed depending on the concentrations of the produced gel samples and the dose amount of the applied radiation.

1. Introduction

Radiation dosimetry and calculation methods are important for the efficient delivery of radiation from devices and avoiding unnecessary doses to the target organ or tissue in cancer treatments. Although radiation is used in the treatment of cancer due to the lethal effect on the tumor cells, normal tissues may be damaged due to overdose.

Current radiotherapy planning systems that calculate the total dose to be given to the patient are based only on theoretical simulations and it cannot be confirmed experimentally whether the radiation dose to the patient is higher than the critical values of healthy organs and tissues. Determination of the three-dimensional (3D) dose distribution given to the patient by the devices working with ionizing radiation used in radiotherapy and radiology is now possible only with gel dosimeters or anthropomorphic phantoms which is the imitation of human body in terms of shape and radiation interaction [1,2].

Tissue equivalent gel-based dosimeters were used as a method to measuring dose distribution and attracted much attention today due to its advantages such as accuracy, 3-D and high resolution, less dependence on energy. There are two basic dosimetric gel groups namely Fricke gels and polymeric gels [3].

Fricke gel is prepared by taking the aqueous iron sulphate (Fricke) solution into a gel matrix. In this system, conversion of acidic, oxygen-enriched aqueous Fe^{2+} ions to Fe^{3+} is the dosimetric basis of the Fricke gel. The amounts of Fe^{3+} ions depend on the energy absorbed by the solution [4]. Modern Fricke gel technology was born with this development. Different materials such as benzoic acid [5], formic acid [6] and alcohol [7] were added to increase the sensitivity of the gel and ferric ion production in response to applied beam. Gluconic acid is an organic acid which is used in food industry and it is a natural constituent of fruits [8]. In this study, it was aimed to produce more sensitive, tissue equivalent gels for the applied radiation dose by adding non toxic, biodegradable calcium chloride($CaCl_2$) or Gluconic acid in to classical Fricke gels.

2. Material and Method

2.1 Production of Fricke Gels

Five different groups of Fricke gels were produced in this study. All of them are mainly composed of 1% gelatin and deionized water. When the acidic $FeSO_4$ solution is added to gelatin and water, this mixture is named as Fricke gel. Initially four different Fricke gels were produced, containing only 0.125 mM, 0.250 mM, 0.50 mM, 1 mM FeSO4. For the production of other dosimetric gels 0.25 - 0.5 M $CaCl_2$ or 0.5 - 1 mM glukonic acid were added in to these four different Fricke

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Table 1. Compositions and names of gels

Name of gel								
Additive	FC1	FC2	FC3	FC4	FL1	FL2	FL3	FL4
$FeSO_4$(mM)	0.125	0.25	0.5	1.0	0.125	0.25	0.5	1.0
$CaCl_2$ (M)	0.25	0.25	0.25	0.25	0.5	0.5	0.5	0.5
Name of gel								
Additive	FG1	FG2	FG3	FG4	FA1	FA2	FA3	FA4
$FeSO_4$(mM)	0.125	0.25	0.5	1.0	0.125	0.25	0.5	1.0
Glukonic acid (mM)	0.5	0.5	0.5	0.5	1.0	1.0	1.0	1.0

gels. Compositions and names of these gels are given in Table 1. Gel fabrication method previously described by Gambarini et al [9]. Deionized 400 ml water heated to 85°C, than 4 g of bovine gelatin was added and mixed at 400 rpm for 5 minutes with a magnetic stirrer under an air flow at 20Lh^{-1}. During the 20 min the solution was left to boil for saturation and then cooled down to 70 °C. The solution was then removed from the magnetic stirrer and the $FeSO_4$ solution was added to each 100 ml sample to give concentrations of 0.125 mM, 0.250 mM, 0.50 mM and 1 mM respectively. The gel solutions were manually mixed for 10-15 seconds and poured into the polyethylene spectrophotometer cuvettes. The samples were maintained at 4 °C until their analyses were done. Figure 1 shows the photographs of gel solution preparation and gel samples in cuvettes before irradiation process.

Figure 1. Gel samples in cuvettes and preparation of them.

2.2 Irridation and determination of MR intensity values of Fricke Gels

Prepared gels were irradiated with linear accelerator x-ray radiation at 6 MV with doses between 0 - 250 cGy with increments of 50 cGy. The samples were maintained at least 30 min at room temperature before the MRI evaluations. Irradiation process and the MR measurements were performed within 24 hours after gel production for increasing the accuracy and sensitivity of the analysis. Figure 2 shows the photographs of irradiation of gels and MR images after irradiation process. Irradiated gel dosimeters are scanned by a 3T MR system (Siemens Skyra, Germany) at T1 weighted sequences in 2 hours after irradiation.

Acquired images are evaluated and MR intensities with standard deviations in ROIs' (Region of Interest) are measured using a software (Siemens, Syngo Via, Germany). FT-IR analyses of Fricke gels were done before and after irradiation process by Vertex 70 FT-IR spectrophotometer in ATR mode.

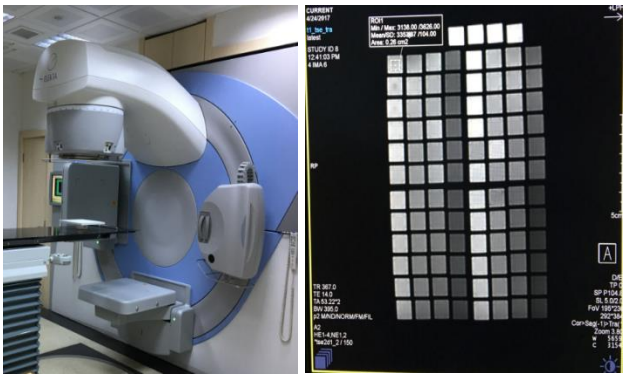
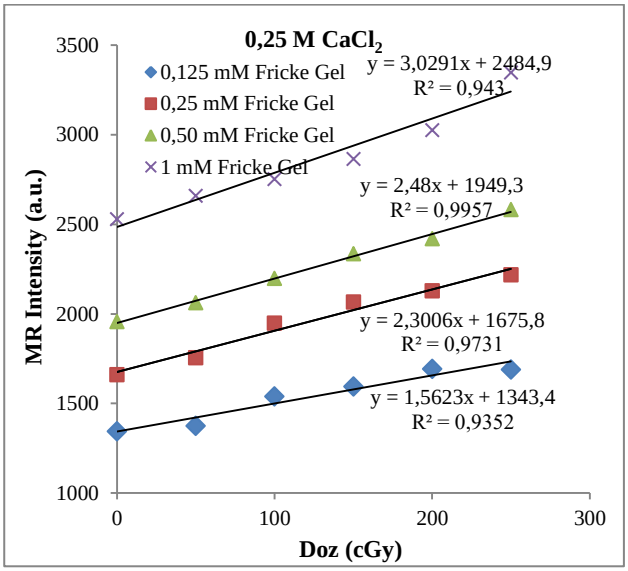


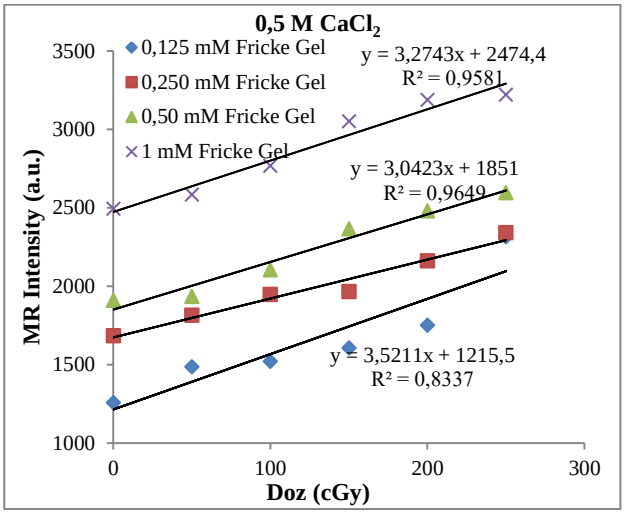
Figure 2. Irradiation process and a MR image of irradiated gels.

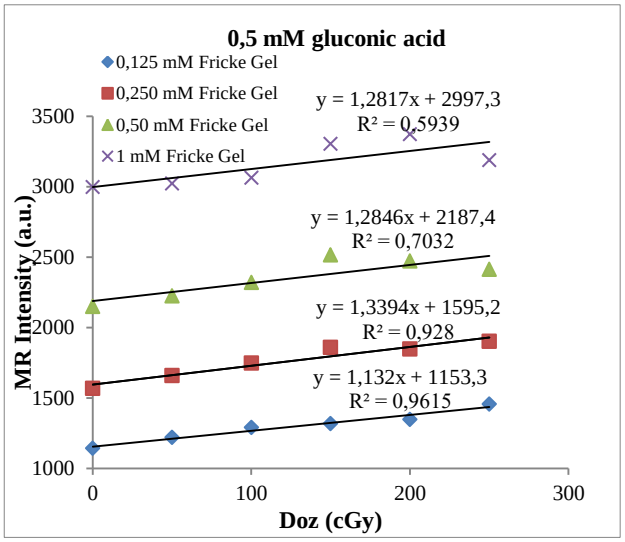
3. Results and Discussion

The MR intensity values obtained from the ROIs were plotted against the irradiation dose and the linear correlation equations were obtained with in Fig 3 Besides all slopes of fitted lines are similar, in Figure 3 it can be seen that highest consistent slope of fitted lines are obtained at FC4, FL4 and FA4 gel dosimeters. This may give the most sensitive radiation dosimeter in these study groups. It is apparent that dose sensitivity increases with increasing of concentration of $FeSO_4$. The increase in dose sensitivity allows dose distribution imaging to be more effective.

As an example the FT-IR spectrum of the FA4 gel before and after irradiation process is given in Figure 4. It is seen that the major peaks in the spectra belong to the gelatin (C-N bond at 1500 cm^{-1}, N-H bond at 3300-3400 cm^{-1}, C=O bond at 1600 cm^{-1}, etc. [10,11]), iron oxide and iron hydroxide (Fe-O at 573-579 cm^{-1}, Fe-OH at 943-993 and 3340 cm^{-1}[12]) given in the literature. It has been observed that the irradiation process does not make a significant change in the FT-IR spectrums of the gels containing gluconic acid, especially at high concentrations.







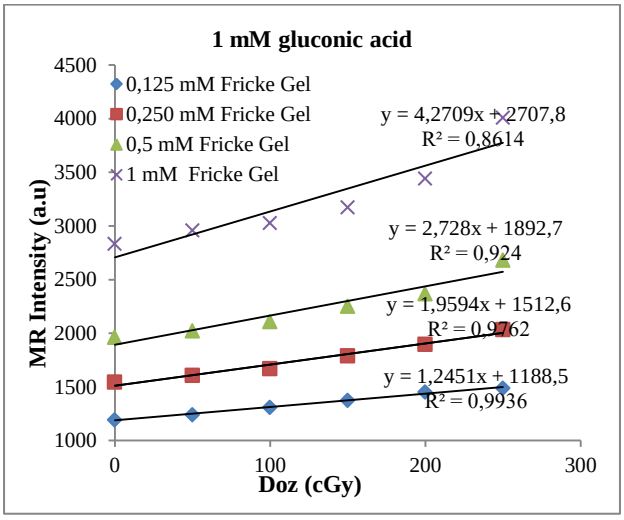


Figure 3. MR intensity values against irradiation dose

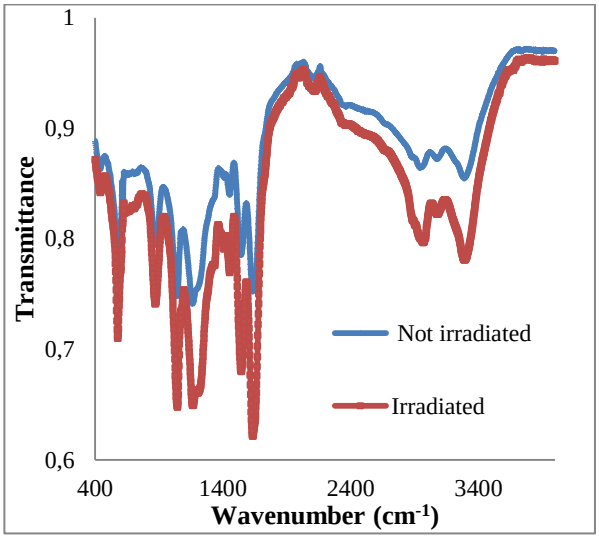


Figure 4. FT-IR spectrum of the FA4 gel before and after irradiation process.

MR images of the gels including 0.25 M $CaCl_2$ is showed in Figure 5. The image brightness increases with increasing $FeSO_4$ concentration and irradiation dose.

As can be seen from the Figure 3, Figure 4 and Figure 5, the produced gel dosimeters give different responses to the doses of the applied radiation. This demonstrates their utility as a dosimetric gel.

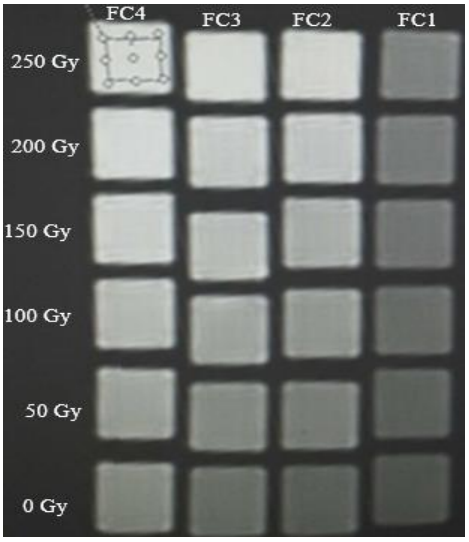


Figure 5. MR images of gels including 0.25 M $CaCl_2$ at various irradiation doses.

4. Conclusions

It is very important to calculate the doses received by cancer patients during radiotherapy treatments. Fricke gel can be more preferred in terms of ease of production. In this study Fricke gels, containing $FeSO_4$ solutions at four different concentrations including $CaCl_2$ or gluconic acid, were produced. The produced gels were irradiated with x-rays at 0, 50, 100, 150, 200 and 250 cGy under 1 cm water equivalent phantom at 6 MV. The MR intensity values were linearly changed depending on the concentrations of the produced samples and the dose amount of the applied radiation. As a result, before a radiotherapy treatment the possible radiation dose distribution in the body of a cancer patient can be determined by these produced gels as a 3D dose imaging system.

The dose sensitivities of the gels can be improved by using $FeSO_4$ and gluconic acid at higher concentrations. $CaCl_2$ can be settled at higher concentrations. Therefore, gels containing at lower concentrations of $CaCl_2$ and higher concentrations of $FeSO_4$ can be researched. Furthermore gels can be developed with different additives. There is urgently need to improve these studies for the cancer patients.

Acknowledgment

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Research Article

Selection of optimal numerical method for implementation of Lorenz Chaotic system on FPGA

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ABSTRACT

In this study, implementation of Lorenz chaotic system on Spartan 3e XC3S1600e FPGA development board by using Xilinx System Generator technology is presented. Differential equations of any nonlinear system have to be discretized before coding and design process on FPGA editor. The Lorenz chaotic system is discretized by using Taylor series expansion, Runge-Kutta and Euler discretization methods which are mostly preferred to discretize the continuous formed signals. The optimal numerical method based on application area is proposed by proving accuracy and complexity of methods and comparing designs in terms of resource utilizations on FPGA board.

1. Introduction

Chaos can be found in many engineering systems [1]. The main characteristic of chaotic system is that it is extremely sensitive to initial conditions and small difference in initial state can cause to extraordinary differences in the system behavior. Chaotic behaviors are complex, irregular and generally undesirable in mechanical systems. In many mechanical system applications require a control unit that minimizes complexity and eliminates undesired behaviors in order to improve performance of the system. However, chaotic behavior can be useful some areas where the complexity is required such as secure communication and cryptographic systems [2].

The dynamics of chaotic systems have attracted increasing attention of researchers in recent years. The Lorenz model [3] describes the motion of a fluid under the conditions of Rayleigh-Benard flow [4] and it has become a paradigm [5]. The system consists of many features of the chaotic dynamics but it is the simplest model for the dynamics of convective layers and close convection loops [6]. In literature, there are many publications related to Lorenz system and comparisons of it between other chaotic systems [7-10].

In the analysis of chaotic system, two representation types confront to us which are continuous time and discrete time modelling. In digital applications, discrete time modelling must be used in order to process the system behavior onto digital processors. For this purpose, there are many discretization methods in literature. When using a discretization method for a digital processing, it is definitely considered by user whether the design has desired accuracy and resource utilization or not. In this study, Taylor series expansion, Euler and Runge-Kutta discretization methods are used to represent differential equations of Lorenz chaotic system in discrete time domain. Selection of the optimal discretization method is important to have desired performance. In [11], Forward Euler (FE) and Runge-Kutta (RK) numerical integration methods are used for simulating the chaotic behavior of multi-scroll chaotic oscillator and results are compared.

In circuit realization studies, Field Programmable Gate Array (FPGA) technology is frequently preferred by designers based upon its high speed parallel processing and low cost area abilities. When FPGA is used for realization of mathematical equations, a fractional

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number representation format must be arranged to design mathematical model. There are two types of fractional number representation format which are fixed-point and floating-point, respectively.

In this study, differential equations of Lorenz system are discretized by using Taylor series expansion, Euler and Runge-Kutta numerical discretization methods in order to compare designs by the meaning of accuracy, complexity and resource utilizations on FPGA. After discretization process, discrete time models are designed on Spartan 3e XC3S1600e FPGA development board by using Xilinx System Generator (XSG) technology. In the design stage, fixed-point number representation format is used.

Herewith this introduction, the Lorenz chaotic system and three different discretization methods are expressed in Section 2. For each discretization methods, discrete mathematical models are defined. In Section 3, brief information about fixed-point number representation format and FPGA design by using XSG technology is given. Also, implementation results of three designs and comparison of discretization methods are illustrated in this section. At the end, final section concludes the paper.

2. The Lorenz System and Discretization Methods

2.1 The Lorenz System

The Lorenz system [3], named for Edward N. Lorenz is a famous example of nonlinear chaotic system. The system has 3-dimensional dynamical model that exhibits chaotic behaviors. The state equations of system are represented as follow;

$$\begin{aligned} \dot{x} &= \sigma \cdot (y - x) \\ \dot{y} &= r \cdot x - y - x \cdot z \\ \dot{z} &= x \cdot y - \beta \cdot z \end{aligned} \tag{1}$$

where σ, r and β are called control parameters and x, y, z are state variables of system. All σ, r, β>0, but usually σ=10, β=8/3 and r is varied. The system exhibits chaotic behavior for r=28 [12].

The system has many features of nonlinearity. MATLAB Simulink block diagram of the system is illustrated in Fig. 1 and simulation result for x-y phase plane portrait is given in Fig. 2.

The chaotic behavior can be quantitatively determined by obtaining maximum Lyapunov exponent (MLE) value [13, 14]. Regarding to simulation time series of the model, MLE values of state variables of the Lorenz system are λ_{1max} = 0.1359, λ_{2max} = 0.0828 and λ_{3max} = 0.0164. Since there are at least two positive MLE value, strong hyper chaotic behavior in the system is quantitatively demonstrated.

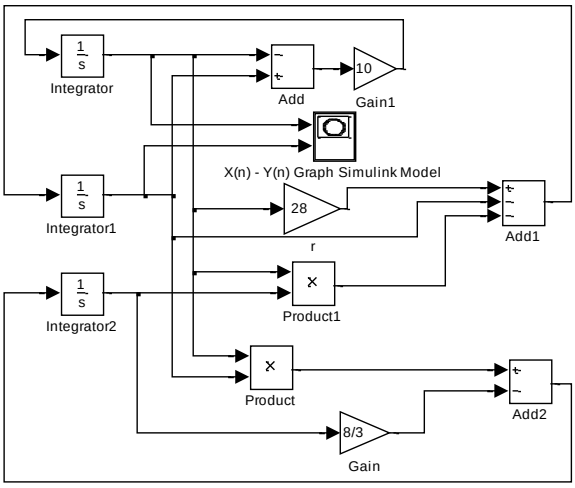

Figure 1. MATLAB Simulink block diagram of Lorenz system.

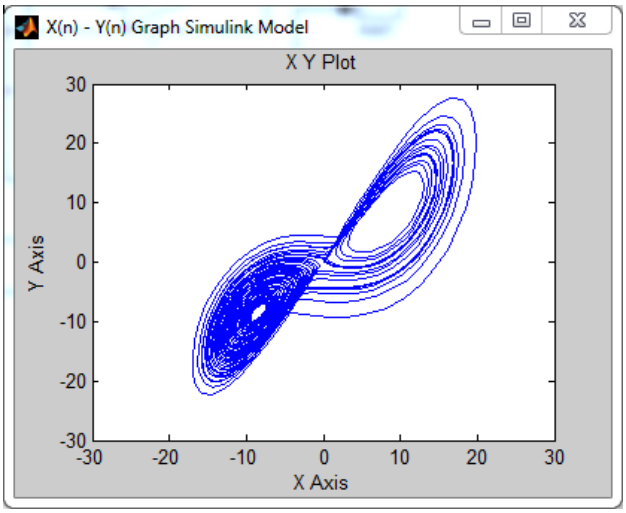

Figure 2. x-y chaotic phase plane portrait of the system.

2.2 Taylor Series Expansion Method

In order to program any system on a microprocessor, system model must be discretized. In Taylor series expansion numerical method, state variables of the Lorenz system are expanded for any m^{th} order as follow.

$$\begin{aligned} x(t+h) &= x(t) + \sum_{m=1}^{\infty} \frac{1}{m!} \cdot h^m \cdot x^{(m)} \\ y(t+h) &= y(t) + \sum_{m=1}^{\infty} \frac{1}{m!} \cdot h^m \cdot y^{(m)} \\ z(t+h) &= z(t) + \sum_{m=1}^{\infty} \frac{1}{m!} \cdot h^m \cdot z^{(m)} \end{aligned} \tag{2}$$

Bearing in mind that this study aims the comparison of numerical methods, Taylor series expansion method is executed for m=2 and h=0.001. In this situation, discrete time state equations of the Lorenz system with Taylor series expansion method is obtained as follow.

$$
\begin{aligned}
x[n+1] &= x[n] + 0,001 \cdot \dot{x}[n] + \frac{1}{2} \cdot 0,001^2 \cdot \ddot{x}[n] \\
y[n+1] &= y[n] + 0,001 \cdot \dot{y}[n] + \frac{1}{2} \cdot 0,001^2 \cdot \ddot{y}[n] \\
z[n+1] &= z[n] + 0,001 \cdot \dot{z}[n] + \frac{1}{2} \cdot 0,001^2 \cdot \ddot{z}[n]
\end{aligned} \tag{3}
$$

$$
\begin{aligned}
&\dot{x}[n] = \sigma \cdot (y[n] - x[n]) \\
&\ddot{x}[n] = \sigma \cdot (r \cdot x[n] - y[n] - x[n] \cdot z[n]) - 10 \cdot \sigma \cdot (y[n] - x[n]) \\
&\dot{y}[n] = r \cdot x[n] - y[n] - x[n] \cdot z[n] \\
&\ddot{y}[n] = r \cdot \sigma \cdot (y[n] - x[n]) - (r \cdot x[n] - y[n] - x[n] \cdot z[n]) \\
&-\sigma \cdot (y[n] - x[n]) \cdot (x[n] \cdot y[n] - \beta \cdot z[n]) \\
&\dot{z}[n] = x[n] \cdot y[n] - \beta \cdot z[n] \\
&\ddot{z}[n] = \sigma \cdot (y[n] - x[n]) \cdot (r \cdot x[n] - y[n] - x[n] \cdot z[n]) \\
&-\beta \cdot (x[n] \cdot y[n] - \beta \cdot z[n])
\end{aligned} \tag{4}
$$

2.3 Runge-Kutta Discretization Method

In literature, the most preferred Runge-Kutta method is 4th order method. Since this study aims to compare discretization methods, 2nd order Runge-Kutta method is preferred. 2nd order Runge-Kutta method is extended for an example in Eq. 5. State variables of the Lorenz system are executed with 2nd order Runge-Kutta method for h=0.001 and discrete time model of the system is represented as in Eq. 6.

$$
\begin{aligned}
&\dot{x}(t) = \frac{dx(t)}{dt} = f\left(x(t), t\right) \\
&k_1 = h \cdot f\left(x(t_0), t_0\right) \\
&x_1(t_0 + \frac{h}{2}) = x(t_0) + k_1 \cdot \frac{h}{2} \\
&k_2 = f\left(x_1(t_0 + \frac{h}{2}), t_0 + \frac{h}{2}\right) \\
&x(t_0 + h) = x(t_0) + k_2 \cdot h
\end{aligned} \tag{5}
$$

$$
\begin{aligned}
&k_{1x} = h \cdot \left(\sigma \cdot (y[n] - x[n])\right) \\
&k_{2x} = h \cdot \left(\sigma \cdot (y[n] - (x[n] + \frac{k_{1x}}{2}))\right) \\
&x[n+1] = x[n] + \frac{(k_{1x} + k_{2x})}{2} \\
&k_{1y} = h \cdot \left(r \cdot x[n] - y[n] - x[n] \cdot z[n]\right) \\
&k_{2y} = h \cdot \left(r \cdot x[n] - (y[n] + \frac{k_{1y}}{2}) - x[n] \cdot z[n]\right) \\
&y[n+1] = y[n] + \frac{(k_{1y} + k_{2y})}{2} \\
&k_{1z} = h \cdot \left(x[n] \cdot y[n] - \beta \cdot z[n]\right) \\
&k_{2z} = h \cdot \left(x[n] \cdot y[n] - \beta \cdot (z[n] + \frac{k_{1z}}{2})\right) \\
&z[n+1] = z[n] + \frac{(k_{1z} + k_{2z})}{2}
\end{aligned} \tag{6}
$$

2.4 Euler Discretization Method

Euler method can be arranged in two ways which are Forward and Backward Euler. In this study, Forward Euler (FE) method is preferred. The expression of FE method is given in Eq. 7 and discretized model is expressed in Eq. 8 for h=0.001.

$$
\begin{aligned}
\dot{x}(t) &= \frac{x(t+h) - x(t)}{h} \\
\dot{y}(t) &= \frac{y(t+h) - y(t)}{h} \\
\dot{z}(t) &= \frac{z(t+h) - z(t)}{h}
\end{aligned} \tag{7}
$$

$$
\begin{aligned}
x[n+1] &= x[n] + h \cdot \sigma \cdot (y[n] - x[n]) \\
y[n+1] &= y[n] + h \cdot \left(r \cdot x[n] - y[n] - x[n] \cdot z[n]\right) \\
z[n+1] &= z[n] + h \cdot \left(x[n] \cdot y[n] - \beta \cdot z[n]\right)
\end{aligned} \tag{8}
$$

3. Implementation Stage

3.1 The Xilinx System Generator (XSG) Technology

The Xilinx System Generator is a high level MATLAB-Simulink based software platform that is used to create fast and easy designs on FPGA boards, execute Hardware Co-Simulation of design and implement real-time onboard applications [15]. XSG has libraries which consists of bit or loop based blocks inside MATLAB-Simulink for applications such as arithmetic, logical, memory and Digital Signal Processing (DSP). The only difference between XSG blocks and common Simulink blocks is that XSG blocks can be used in discrete-time domain with fixed-point number representation format.

3.2 Fixed-point Number Representation Format

In this study, 32-bit signed fractional numbers are used in arithmetic operations such as addition and multiplication process. In order to use in a design fractional numbers, there are two ways in literature that are floating-point and fixed-point number representation formats. In the design process of discrete time model equations, 2's complement 32-bit fixed-point number format is preferred. *Qm.n* is used for representing fixed-point number format where *m* indicates

the number of bits that are arranged for integer part of number while *n* for fractional part. Therefore, the format is arranged as *Q16.16* and illustrated in Fig. 3. The resolution of the format is obtained as $2^{-n} = 2^{-16} = 1.5259$ e-5 [16].

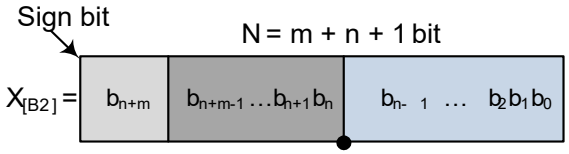

Figure 3. *Qm.n* fixed-point number representation format.

3.3 Implementation Results and Comparisons

In the implementation stage, discrete time models that are discretized by three numerical methods are designed on Spartan 3e XC3S1600e FPGA development board by using XSG platform with 32-bit signed 2's complement fixed-point number representation format in real-time. Change of *x* state variable for each one of three methods design and Simulink reference model is shown in Fig. 4.

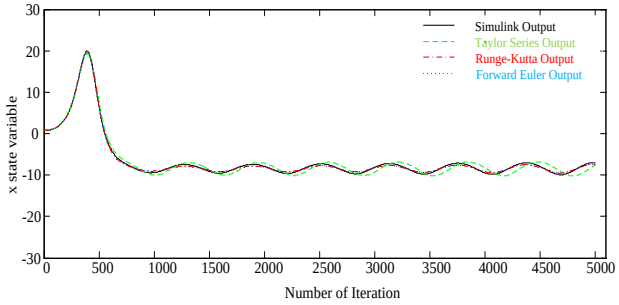

Figure 4. Change of each *x* state variable of designs.

In order to compare designs by meaning of accuracy and complexity, mean square error (MSE) and maximum Lyapunov exponent (MLE) values are determined. Table 1 represents MSE and MLE values of designs that are used to discretize the Lorenz system.

Table 1. Mean Square Error (MSE) and Maximum Lyapunov Exponent (MSE) values of designs.

Discretization Method	MSE	MLE		
		λ_{1max}	λ_{2max}	λ_{3max}
Taylor Series Expansion	0.6742	0.0295	0.0249	0.0021
Runge-Kutta	0.0884	0.0980	0.0075	0.0074
Forward Euler	0.0874	0.1103	0.0077	0.0086
Simulink Model	-	0.1359	0.0828	0.0164

In Taylor series expansion method, 2nd order expansion is executed. Therefore, the MSE value of this method is nearly eight times higher than the others. Considering results of Table 1, FE discretization method can be used with greater accuracy and complexity. Implementation results for *x-y* phase plane portrait of each one three methods are given in Fig. 5 (a), (b) and (c).

The screen views of three designs with discretization methods on XSG platform are illustrated in Fig.6, 7 and 8. Table 2 and 3 represent number of arithmetic circuits, XSG blocks and resource utilization on FPGA for each discretization method.

Table 2. Number of used arithmetic circuits and XSG blocks

Arithmetic circuits and XSG blocks	Taylor Series	Runge-Kutta	Forward Euler
Addition	6	9	3
Subtraction	8	6	1
Multiplication	18	16	8
Register	3	3	3
Constant	15	15	7

Table 3. Resource utilizations on FPGA for each method.

FPGA resources	Taylor Series	Runge-Kutta	Forward Euler
Used Logic Slices	2146	1856	888
Used Flip-Flops	3225	2624	1360
Used LUTs	3719	3248	1496
IOBs	96	96	96
Mults/DSP48s	78	64	32

As seen in Table 2 and 3, FE method uses almost half of both XSG blocks and FPGA resources that RK and Taylor series methods use.

4. Conclusions

As a result of this study, it is clearly understood that Forward Euler discretization method has the best performance for discretization of the Lorenz chaotic system. However, Runge-Kutta method has better accuracy and uses less resource on FPGA than Taylor series. Also, in the implementation stage Taylor series expansion method is executed for 2nd order. If the order of expansion is increased, accuracy of Taylor series expansion method can get better while MSE value decreases. On the other hand, resource utilization of higher order Taylor series expansion method increases.

As a future work, the Lorenz chaotic system circuitry will be installed on board. The similar work will be processed on board by using basic circuit elements and signal converters as digital to analog and vice versa.

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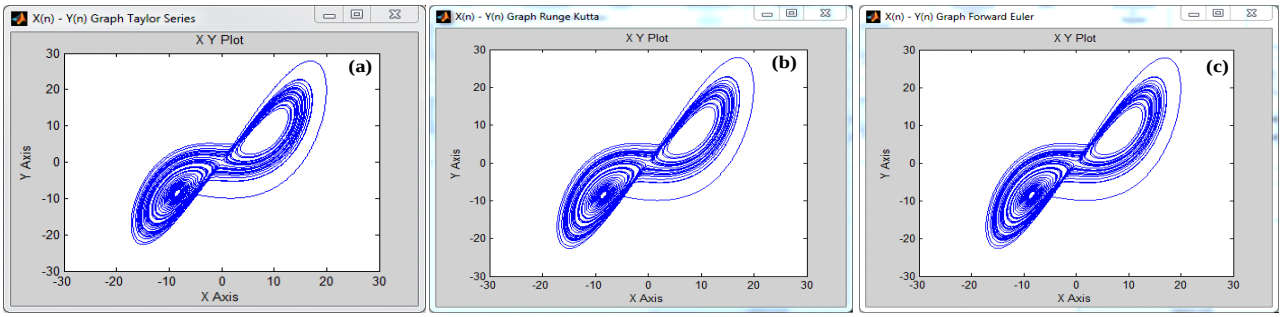

Figure 5. *x-y* chaotic phase plane portrait for the design with a) Taylor series expansion, b) Runge-Kutta and c) Forward Euler.

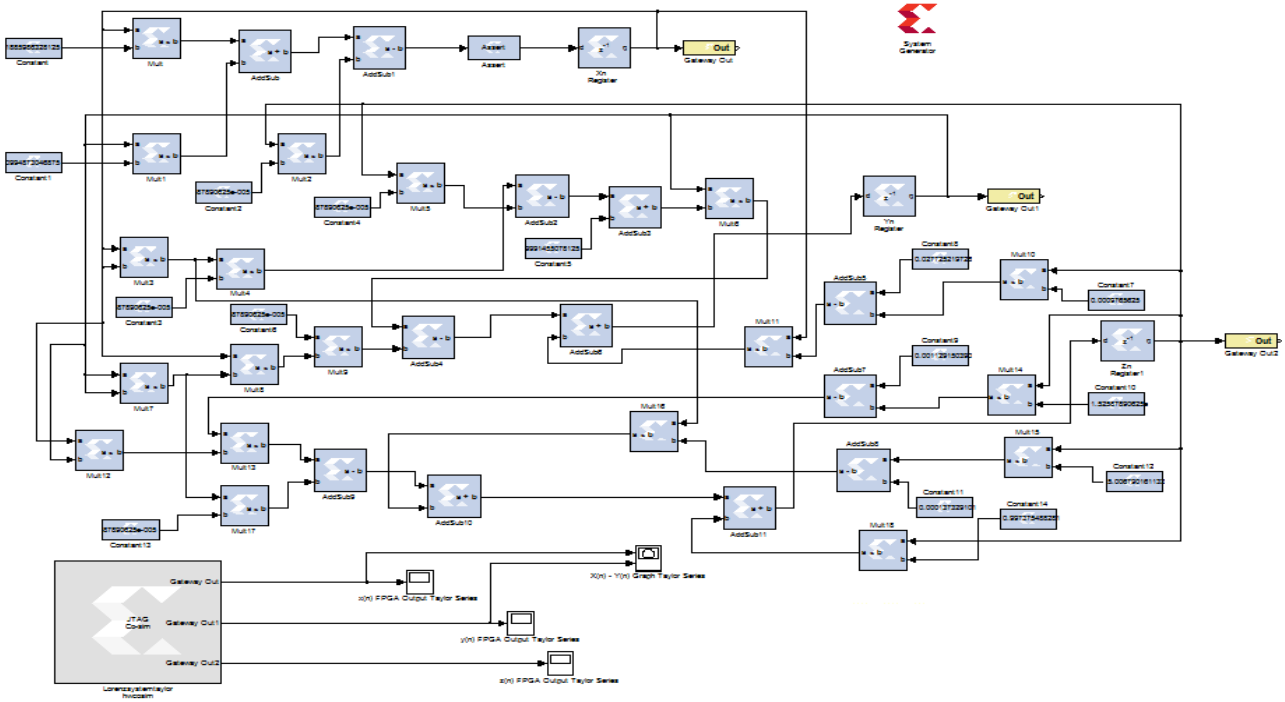

Figure 6. Implementation view of Lorenz system with Taylor series expansion method on XSG platform.

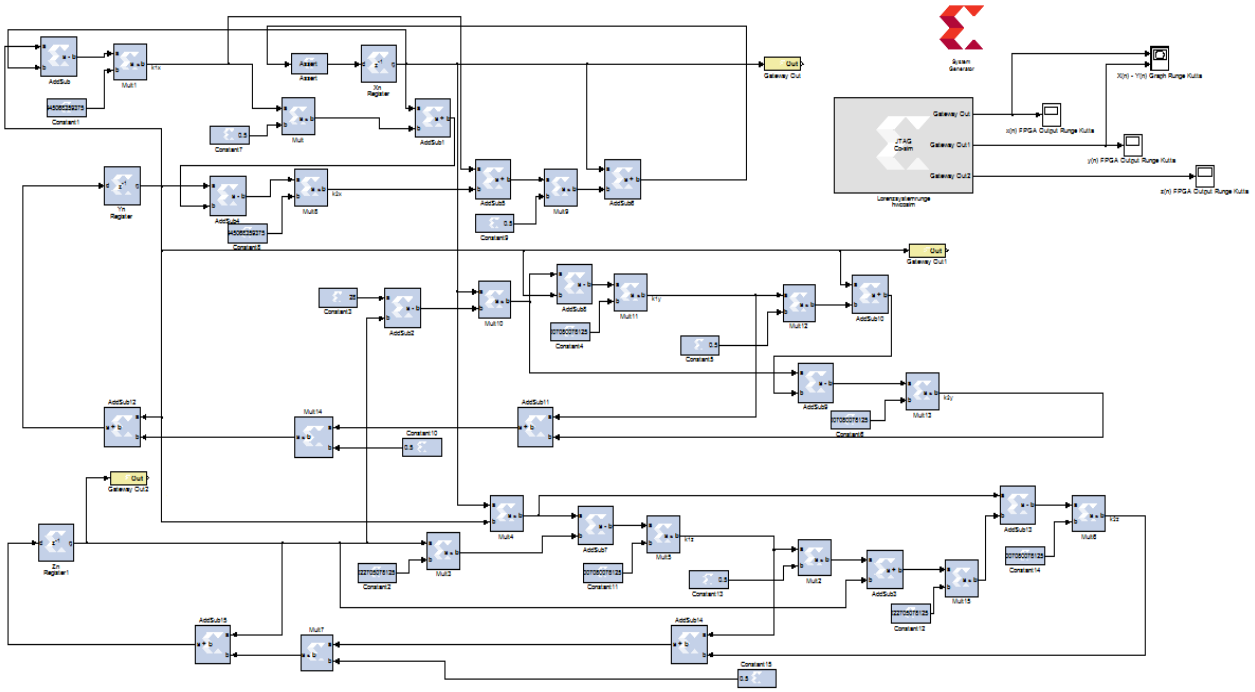

Figure 7. Implementation view of Lorenz system with Runge-Kutta discretization method on XSG platform.

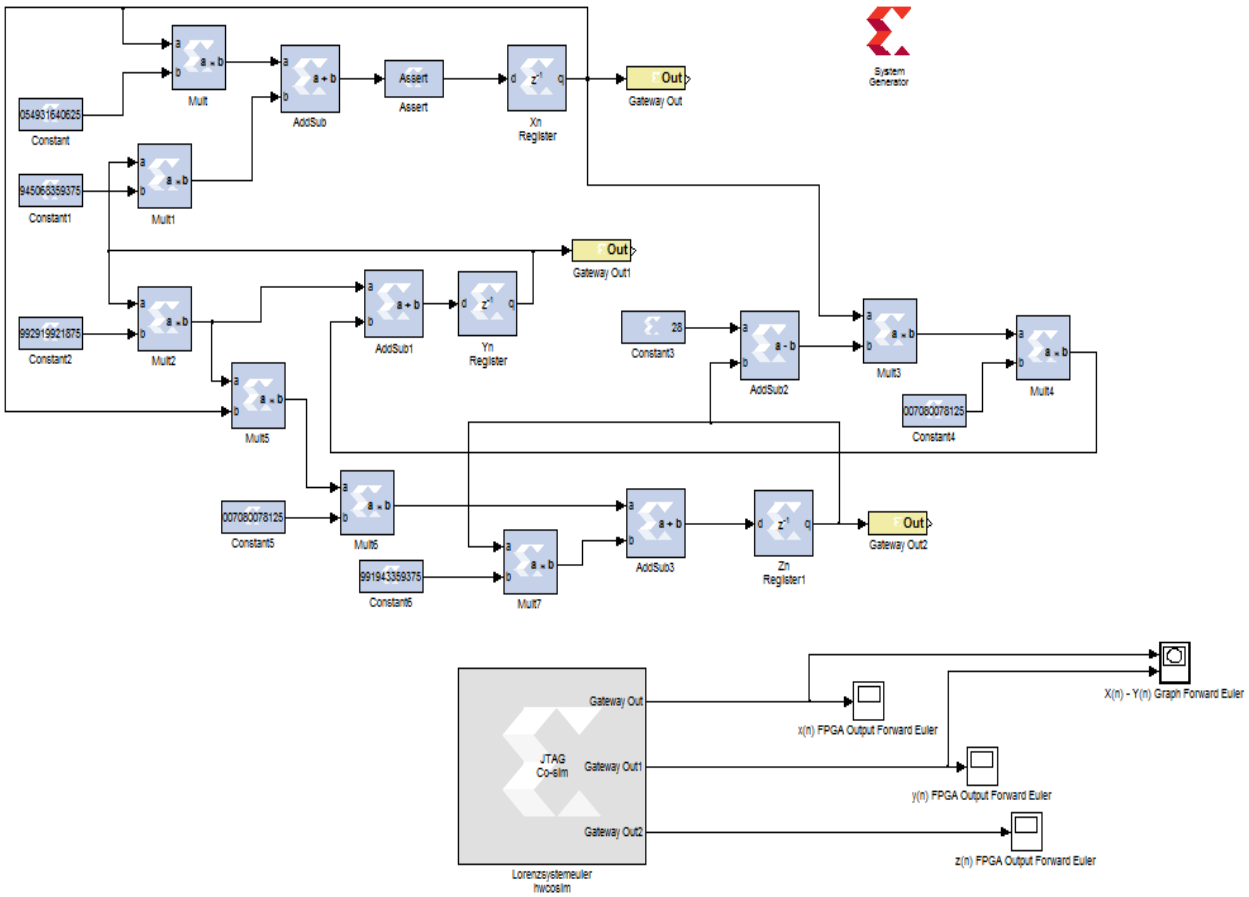

Figure 8. Implementation view of Lorenz system with Forward Euler discretization method on XSG platform.

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Research Article

Design and production of a fixed anode x-ray tube

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ABSTRACT

Nowadays, *X*-ray has had a wide range of applications in nuclear imaging, medicine, and industry. In our country, *X*-rays are widely used in these fields. However, we are in dependence on foreign sources on the *X*-ray devices. In our study, it is aimed to design a fixed anode type *X*-ray tube which is essential in medical imaging techniques by using the local opportunities, to carry out production of a prototype and to observe the *X*-rays experimentally. As a result, an *X*-ray tube is designed and three *X*-ray tube prototypes are manufactured by forming of Pyrex glass. *X*-rays are measured by using dental *X*-ray film and Geiger Muller counter.

1. Introduction

Since the exploration of *X*-rays, they have been used on various and important fields in daily life by the reason of their short-wavelength and high energy. It is being used as a device for prognosis and treatment in medicine, to detect the stiffness of metals especially for cast or welded components in industry, as a researching tool in chemistry and physical science as in *XRF (X-ray fluorescence)*, *XRD (X-ray Diffraction)*, and other *X*-ray devices.

The study was started by discussing the question "Is it possible to produce *X*-ray tools with domestic resources?". After a long time of researches, some questions were answered such as what kind of ray *X*-ray was, which *X*-ray production technique could be used, and which manufacturing technologies had to be applied. Ultimately, materials to be used were determined and necessary process steps were decided to apply. If the high-voltage circuit is applied between well placed anode-cathode in a vacuum chamber, *X*-rays can be obtained and a prototype *X*-ray tube can be produced [1-2]. *X*-ray tubes are divided into two types as *fixed anode* and *rotary anode* [3]. An *X*-ray tube consists of *anode* and *cathode* elements placed inside a glass tube where its air is removed by means of high vacuum [4].

The anode material consists of a thick rod and a metal target at the end of this rod. The material of anode is very important because it determines the type and amount of electron to be released. For example, *Cu* metal can conduct *X*-rays when an electron arrives on it [5]. The cathode is made of tungsten material and called filament [6]. It releases electron when heated. When the filament is fed with an *AC* source, it starts heating. So electrons on the tungsten material reach high speed and kinetic energy. High speed electrons flow toward copper metal and collide with a copper atom. The electron may have to collide with many atoms until it is stopped. When electron stops, one percent or less of its kinetic energy is converted to some *X*-ray radiation and the remainder to heat energy [7-9].

The power of *X*-rays to penetrate into the material is called "hardness". The hardness of these rays depends on two main parameters. First one is vacuum quality. The more vacuum leads to the less number of remaining gas molecules in the tube. It results in the less impact of electron to remaining gas molecules and the less deviation from target. Second factor is the applied voltage, namely the electrical pressure. The higher voltage results in the bigger impact effect of electron flow [10].

In this study, firstly, a fixed anode *X*-ray tube was designed and prototype tubes were manufactured by

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adhering to this design. As a result, an *X*-ray tube was produced and electromagnetic *X*-ray waves ranging from 0.1 to 100 *Å* in wave length were observed experimentally.

2. Method and Material

2.1 X-Ray Tube Design

The design of the *X*-ray tube was done in Solid Works™. The *X*-ray tube consists of 6 parts in total. The tube design created by mounting of solid models of whole components is given in Figure 1.

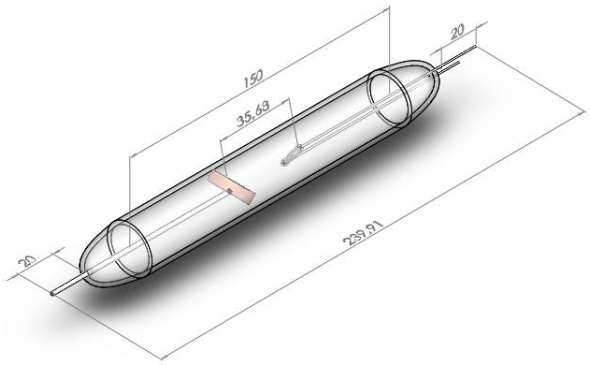

Figure 1. Designed X-ray tube

After the *X*-ray tube is designed, the bottom plate is used to accommodate the power sources and the tube together. Installation is shown in Figure 2.

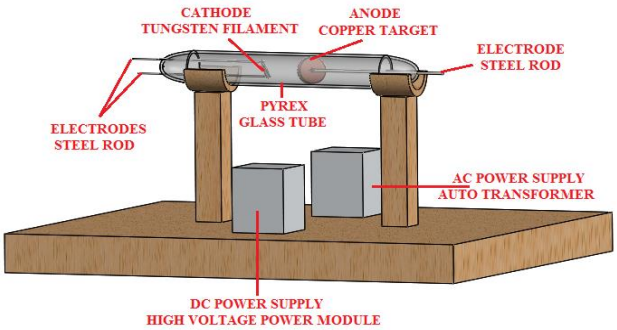

Figure 2. Montage schema of complete system

2.2 System Manufacturing

After the tube design, the manufacturing stage has been started.

Firstly, anode material is prepared. A copper bar is machined by a lathe machine to obtain *Cu* target. The copper target is brazed to steel electrode using gas welding. Besides, surface polishing is done to get more rays from the target material. The surface of the target material is gradually sanded from coarse to finer sandpapers by using 350, 500, 1000, 2200 and 4000 grids containing silicon carbide grains and magnetite powder. A produced anode material is shown in Figure 3.

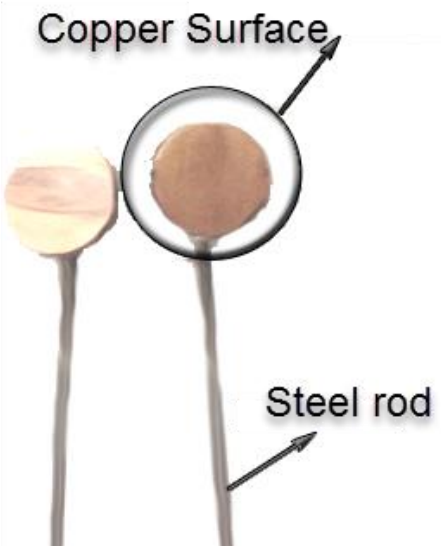

Figure 3. Anode (copper target)

Later, the cathode preparing process has been started. The cathode is negative terminal of the *X*-ray tube. The cathode is called "*filament*" too. The filament is a winding of tungsten alloy wire in cylindrical shape with outer diameter of 2 mm and a length of 1-2 cm. The reason for using tungsten is that it has high heat-resistance (up to 3410 °C) and emits more thermionic emissions. In order to allow electrons to leave filament metal in the thermionic emission, electrons must be given at least *W* energy, which is defined as a function of work applied on the filament metal. The count of electrons leaving filament metal in a unit time increases with the temperature of the filament depending on metal used. In the case of energy greater than *W*, the electrons leaving the filament surface will have some kinetic energy. Filament is heated by passing a low AC current inside in order to load kinetic energy on electrons and accelerate them and so it will be ready for high temperature shock. The applied voltage and current approximate 3 to 6 amperes result in heating of more than 2200 °C due to the high resistance of filament material. In the heated filament, electrons in the outer orbital of the tungsten atoms liberate and separate from filament surface and thermionic emission occurs.

Since the tungsten element has a brittle microstructure, filament formation is very difficult. So tungsten wire is heated by using oxy-acetylene flame and bended into cylindrical shape. Finally both ends of filament winding are brazed to steel electrodes as seen in Figure 4.

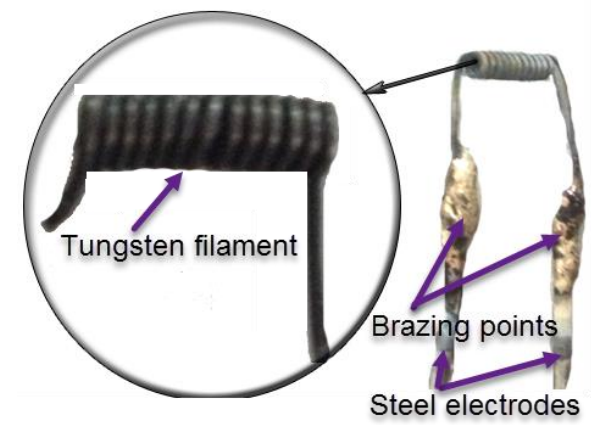

Figure 4. Cathode (tungsten filament)

After the anode and cathode elements are prepared, these two materials were appropriately inserted into a Pyrex (borosilicate) glass tube. Pyrex glass has high temperature resistance and makes rays up to 3000 Å passed through and has low heat expansion coefficients. Pyrex glass is processed at high temperature of approximate 3200 °C, by using flame, a mixture of 50% oxygen and 50% acetylene gases. Anode element is placed on one side of the Pyrex glass and after it is sealed.

Another narrower Pyrex glass tube with 2 mm inner diameter is attached to the tube as vacuuming port on the glass tube. After the implementation of the anode element and vacuum port, finally, the cathode element is assembled to glass tube. An image taken during operation is shown in Figure 5 and the assembled *X*-ray tube is given in Figure 6.

Figure 5. Stage of placement of anode-cathode elements

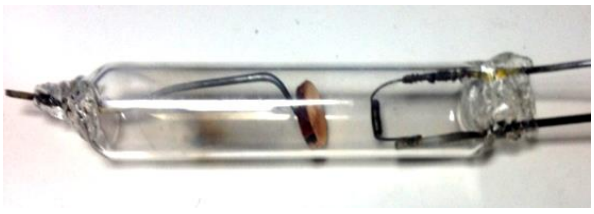

Figure 6. Anode-cathode elements placed in Pyrex glass tube

Inside Pyrex glass tube, anode-cathode elements and the narrower tube for vacuum are mounted properly. Later, epoxy adhesive treatment is applied to the ends of the tube for sealing precisely. Also an epoxy adhesive fills the cracks for preventing of crack propagation. The image after applying the epoxy is given in Figure 7. But epoxy breaks down at high temperature. So, epoxy will be useful unless reaching high temperatures. For commercial application of the tube, it is compulsory that a leak proof connection has to be done instead of epoxy due to high temperatures or long application times.

Figure 7. Produced X-ray tube

2.3 Experimental Setup

In our experimental rig system, vacuum is applied during working. During vacuuming, an *AC* power source is connected to the filament (cathode) side, finally, the high voltage source is connected to the *X*-ray tube.

The vacuum is applied to remove any gas molecules inside the tube, so that accelerated electrons can reach the target without colliding with the gas molecules inside the tube. When inside of tube is vacuumed perfectly, gas ionization is avoided in the *X*-ray tube completely. Besides, the vacuum of the tube is necessary for long life and effective *X*-rays. Figure 8 shows vacuum pump and *X*-ray tube used.

Figure 8. Vacuum application to the X-ray tube

It is necessary to heat the filament about 2200 °C so that electrons of the tungsten atom can break off from the filament surface. Heating can be controlled by using a variac (auto transformer or other name *AC* voltage power supply). The high voltage power supply used in the system is a *R* 179 model, *DC* 40 KV ignition coil power module. An image of the connection of the auto transformer and the

power module to the *X*-ray tube is shown in Figure 9.

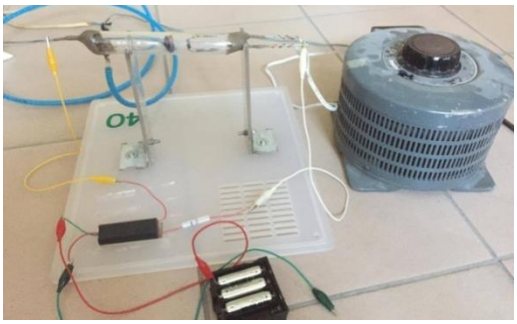

Figure 9. Connecting power supplies

The *X*-ray tube becomes ready for use after the vacuum, auto transformer (variac), and the *DC* high power module are connected to Pyrex glass tube.

2.4 Experiments

In this study, *X*-rays are applied by two different methods. First method is directing of rays to on *X*-ray film. In the experiment, self-bathroom dental *X*-ray films are used. This method is not accurate due to difficulty for calibration. Also these films are affected by temperature and humidity and not reusable but still used as a successful method for getting fast results. Figure 10 shows the experimental system with dental film.

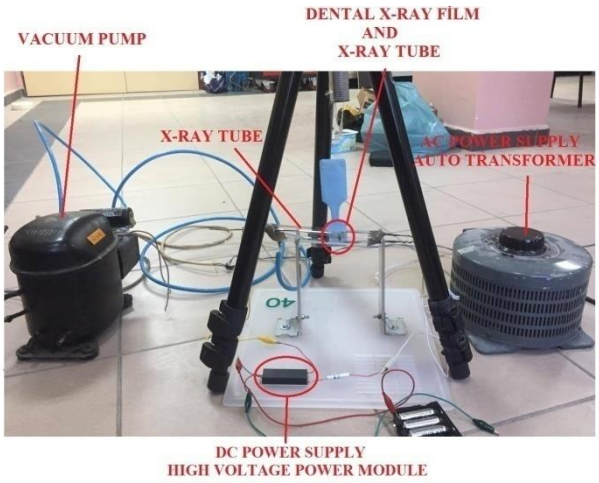

Figure 10. Experimental system

Figure 11 shows that the system is started and rays are directed on the dental film.

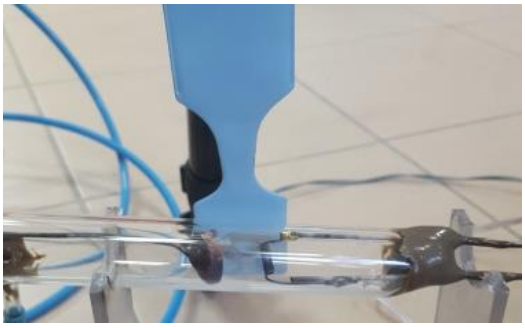

Figure 11. Dental X-ray film and X-ray tube

A Geiger-Muller counter which measures radioactivity is used in the second method. This counter detects any nuclear radiation resulting from *X*-rays by using ionization produced by the low-pressure gas (He-Ne) inside the Geiger-Muller tube which gives the name of the device. The Geiger-Muller counter used is seen in Figure 12. Experimental rig system is given in Figure 13.

Figure 12. Geiger-Muller counter and X-ray tube

The test system shown in Figure 13 detects the nuclear radiation originated from *X*-rays. When the Geiger-Muller counter is getting closer to the *X*-ray tube, it detects the *X*-rays emitted and transfers data to software by a computer and the computer graphically displays number of counted *X*-rays with respect to time.

Figure 13. All of the experimental system of Geiger-Muller counter

3. Results and Discussions

In this work, so called fixed anode *X*-ray tube is design and produced. The design process is realized with Solid Works™ three dimensional solid modeling program. After design, glass processing for placing the anode-cathode materials is done by means of oxy-acetylene flame.

The obtained image by using dental film is given in Figure 14.

Figure 14. A flue image formed on dental film

The image couldn't be obtained clearly by that method but a flue image formed already on film proves existence of the *X*-rays. The reason why the image couldn't be obtained clearly is that the photographic film (dental film) is inefficient in absorbing *X*-rays. These films can absorb only 2% of incoming photons. To increase this ratio in commercial applications, a screen is put behind films. Our experimental system hasn't any monitoring screen.

Screen material is generally composed of fluorescent materials (Calcium-tungsten, cesium-iodide). When *X*-rays arrives at screen, rays are absorbed by screen and stimulate electrons on this screen. It causes more ionization and the absorption efficiency goes up to very high levels and a clear image is obtained.

In the Geiger-Muller counter method, Geiger-Muller counter can show number of ionization events. In other words, it can prove precisely existence of the *X*-ray. It can't determine energy and other characteristics of the ray. Figure 15 shows the results obtained.

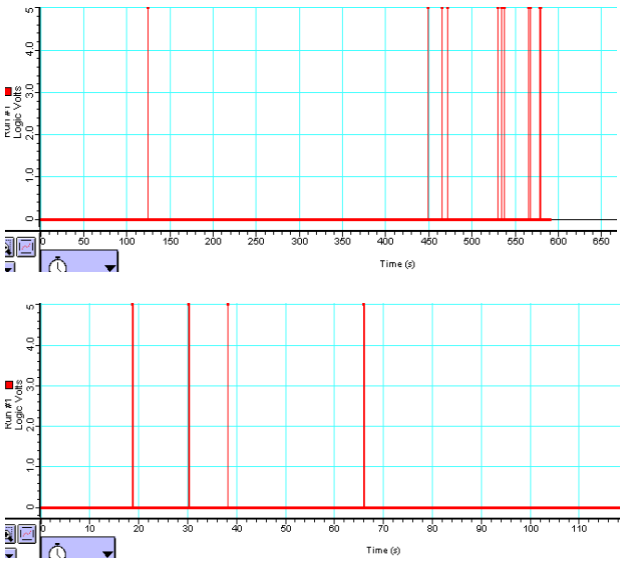

Figure 15. Logical value of X-rays counted by time

When the *X*-ray tube is started to emit *X-rays*, counter will detect and logically display a pick value on the screen.

Because Geiger-Muller counter can only determine if *X*-ray radiation occurs. Two graphics show logical values. Logic 1 value is seen as 5.0 V in the graphic.

The results of two different experiments are shown on graphics in Figure 16 as exist or not exist. In other words, graphics show ionization events occurring during test. In the first graphic, the *X*-ray tube is run for 125 seconds and in the second experiment for about 600 seconds.

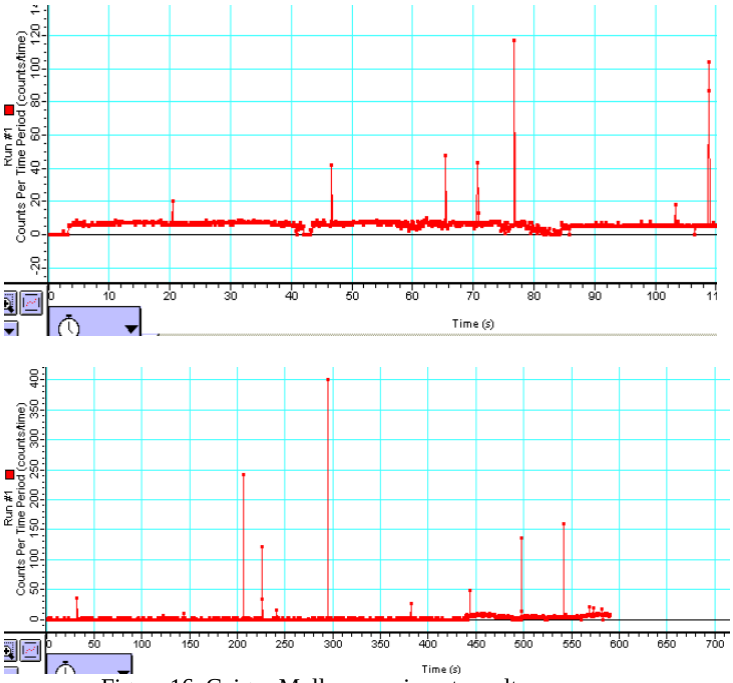

Figure 16. Geiger-Muller experiment results

4. Conclusions

With this study, an *X*-ray tube, which is basic part of an *X*-ray machine is designed and manufactured. The one of remaining two basic partitions is a *control console* that includes an on/off switch, control buttons allowing the operator to obtain the desired amount of *X*-ray, some indicators for *KV* and *mA* values, a regulator which compensates incoming current. The second partition is a *high voltage generator*. It is placed inside a tank full of oil. It also includes voltage-boosting transformers, filament transformers and rectifiers. Oil is an electrical insulator and allows these elements to be located side by side placement inside oil. When these three basic parts are come together, there will be a full *X*-ray device.

With this work, the design and manufacture of an *X*-ray tube has been realized and the prototype costs 33.5 Turkish Liras. Thus, *X*-rays can be produced at very low cost.

Acknowledgment

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Nomenclature

AC :Alternative Current
DC :Direct Current
KV :Kilovolt
Å :Ångström
W :Energy
mA :Miliampere

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Research Article

Examining absorbency properties of the pile loop knitted fabrics with moisture management tester

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Pile yarn
Ground yarn
Sinker height

ABSTRACT

Pile loop knitted fabrics including the form-fitting properties of single jersey are much popular and generally used in clothing such as leisurewear, sportswear, sock etc. though they are terry fabric and the using with the aim of drying expectation. In this study, water absorption properties of pile loop knitted fabrics were investigated in a moisture management tester. For this purpose, twelve pile loop knitted fabrics were obtained by using 100% carded cotton ring spun yarns with Ne 30, Ne 24 yarn numbers as pile yarn, and 100% polyester filament yarn with 70 denier and 90 denier as ground yarn at three different sinker heights which are 2.2 mm, 2.5 mm and 2.8 mm. After knitting, pile loop knit fabrics were dyed in the same processes including scouring, dying, and washing processes. Physical properties of the fabrics were measured according to relevant standards. As for absorption properties of the fabrics were determined according to AATCC 195 standard in SDL Atlas Moisture Management Tester. The study revealed that bottom absorption rate and spreading speed is higher than top absorption rate and spreading speed for all pile loop knitted fabrics. The pile loop knitted fabrics having higher pile show slightly better absorption rate in comparison the pile loop knitted fabrics having lower pile. For different pile heights, top absorption rate is less influenced by pile yarn count whereas bottom absorption rate much affected. Liquid transport capability (OWTC) of the pile loop knitted fabrics containing coarse pile yarn in low sinker height is better, whereas it is better in the fabrics containing fine pile yarn in high sinker height. Moisture management performance (OMMC) is higher in the fabrics having low sinker height, fine ground and pile yarn.

1. Introduction

Knitted terry fabrics are produced that ground yarn and pile yarn are fed to needles in the knitting area according to pile loop knitting technique. They have a wide range of usage from clothing to home textiles. The usage for clothing requires that these fabrics have particularly good moisture and thermal comfort properties. The comfort properties of the fabrics can be measured thanks to the developed devices such as MMT, Alambeta, and hot-plate.

The elongated pile loops are plated on the normal-length ground loops on the technical face of the fabric. The pile loops show as a pile between the wales on the technical back of the fabric (Figure 1) [1].

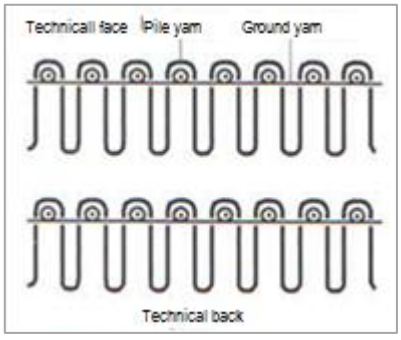

Figure 1. Needle diagram of pile loop knitted fabric

The pile of knitted terry fabric is made by sinkers whose nibs are larger than standard sinkers (Figure 2). This nib is protruding in the pile loop sinkers whereas it is flat in standard sinker [1].

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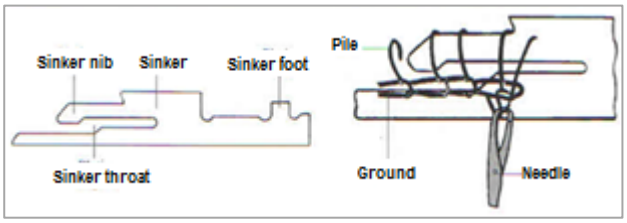

Figure 2. Pile loop sinker

In knitting terry machines, the pile yarn is laid on the pile sinker (Figure 3). Here, the yarn held by the nib of the sinker is pulled by the needle on both sides of the sinker to form the bow. This bow structure is seen as a pile on the fabric [1].

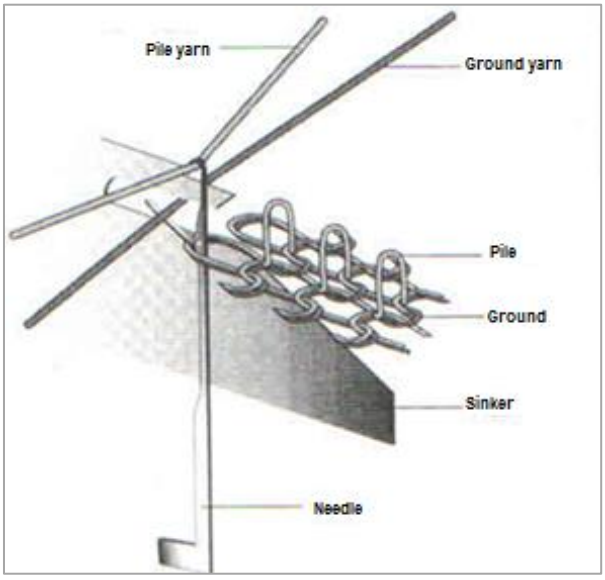

Figure 3. The formation of pile loop

The transfer of fluid with the absorption of moisture or liquid is an important feature in the comfort of the garments. Liquid absorbency depends on the type of fiber raw material and is affected by the hydrophilic or hydrophobic character of the fiber. Hydrophobic fibers (usually synthetic fibers) that have little or non-affinity to the water molecule exhibit little or no fluid absorption while hydrophilic fibers (natural and regenerated fibers, etc.) are attracted to the water molecule exhibiting high fluid absorption. The transfer of liquid in the garments is mainly influenced by the liquid absorption due to the type of raw material, capillarity of the fibers and yarns, the yarn production method, the surface forming technique, the fabric structural parameters and the finishing process applied to the fabric.

The removal of the moisture from the human body in vapor and liquid form is defined as moisture management of a fabric. In SDL Atlas MMT (Moisture Management Tester) (Figure 4), the dynamic fluid or moisture management properties of the fabrics in three dimensions can be measured. The electrical resistances of textile materials are very high. Resistance decreases when they are wet or moist [4]. MMT tester operates on the principle that the contact electrical resistance changes with the liquid presence of the fabric, and the amount of liquid in the fabric is determined from the difference between the voltages on the circuit [5].

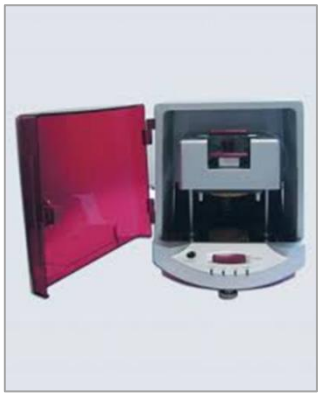

Figure 4. MMT tester (SDL Atlas)

In MMT, the measurement sensors measure the resistance difference (Figure 5). The device contains coaxial circle profiled humidity sensors where the fabric is placed in contact with and tested. The amount of test solution defined in the method and standards is left on the top surface of the fabric by the device during the first 20 second period of the 2 minute test period. MMT detects and measures the transfer behavior of the test solution transferred in three directions in the fabric [6].

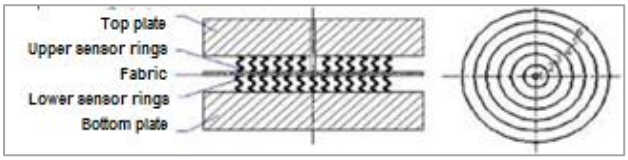

Figure 5. The measurement sensors and rings in MMT

The amount of liquid moisture in the fabric has a characteristic that is expressed parabolically with the drip of the liquid cloth, expressed by the curves U1 and U2 and parabolically decreasing with the liquid absorption of the fabric (Figure 6) [6].

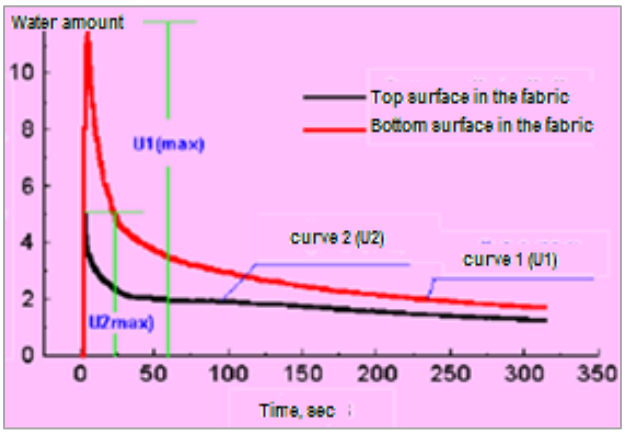

Figure 6. Changing of water amount on fabric surfaces [6]

One way transport capability (OWTC) is the difference in the amount of cumulative liquid (moisture) between the two surfaces of the fabric [7] and is one of the factors affecting the level of drying of the fabric. The calculation

of OWTC is given in Equation 1.

OWTC = (Area (U1) - Area (U2)) / Test duration (1)

U1: Water amount in fabric bottom surface

U2: Water amount in fabric top surface

OWTC values with minus signs indicates that the U2 curve area is larger than the U1 curve area, that is, the transmission of liquid moisture from the fabric top surface to the bottom surface is weak [6].

OMMC (overall moisture management capacity) is an index that determines the total transfer capacity of the liquid in the fabric [7]. The calculation of OMMC is given in Equation 2.

OMMC = C1 * BAR + C2 * OWTC + C3 * BSS (2)

Bottom absorption rate: **BAR**

One way transport capability: **OWTC**

Bottom spreading speed: **BSS**

Coefficients values; C1= C3 = 0.25 and C2 = 0.5

The good value of OMMC indicates that the liquid is effectively transferred from top surface to bottom surface, that the rate of absorption of the liquid transferred to bottom surface is higher and spreads rapidly. MMT scale values are given in Table 1.

Table 1. MMT scale values [8]

Index		Scales				
		1	**2**	**3**	**4**	**5**
Wetting time (sec)	**Top**	≥120 no wetting	20-119 slow	5-19 moderate	3-5 rapid	<3 very rapid
	Bottom	≥120 no wetting	20-119 slow	5-19 moderate	3-5 rapid	<3 very rapid
Absorption rate (%/sec)	**Top**	0-9 very slow	10-29 slow	30-49 moderate	50-100 rapid	>100 very rapid
	Bottom	0-9 very slow	10-29 slow	30-49 moderate	50-100 rapid	>100 very rapid
Max wetted radius (mm)	**Top**	0-7 no wetting	8-12 small	13-17 moderate	18-22 rapid	>22 very rapid
	Bottom	0-7 no wetting	8-12 small	13-17 moderate	18-22 rapid	>22 very rapid
Spreading speed (mm/sec)	**Top**	0,0-0,9 no wetting	1,0-1,9 slow	2,0-2,9 moderate	3,0-4,0 rapid	>4,0 very rapid
	Bottom	0,0-0,9 no wetting	1,0-1,9 slow	2,0-2,9 moderate	3,0-4,0 rapid	>4,0 very rapid
OWTC (%)		<-50 very bad	-50-99 bad	100-199 good	200-400 very good	>400 excellent
OMMC		0,0-0,19 very bad	0,2-0,39 bad	0,4-0,59 good	0,6-0,8 very good	>0,8 excellent

The fabrics are defined below according to MMT scale values [8]:

- Waterproof fabrics
- Water-repellent fabrics
- Slow absorbing and slow drying fabrics
- Rapid absorbing and slow drying fabrics
- Rapid absorbing and rapid drying fabrics
- Water permeable fabrics
- Moisture-sensitive fabric (moderate/rapid absorbing and wetting, rapid dispersion on the surface, spreading and wide spreading area, good/excellent OWTC)

The previous works related to the subject are briefly summarized below.

Chattopadhyay and Chauhan [9] found that the height of the capillary wetting for ring yarns is higher than that of compact yarns, and also coarse yarns have a higher capillary wetting than thin yarns.

Chen et al. [10] researched that the liquid absorption properties of textile materials and one way transport capacities on double layered knitted structures. They indicated that the multi-layer knitted structures exhibit faster absorption and liquid setting properties than the conventional structure.

Prahsarn [11] determined that the fabric liquid absorption capacity is largely dependent on the fabric thickness, than the properties of the blended fibers, and also the fabric thickness, yarn count and fabric tightness are influential on the absorption capacity.

Jiao et al. [12] investigated that thermal and mechanic comfort properties of the clothes made of hydrophilic polyester and hydrophobic polyester fabrics. They found that capillary wetting and liquid moisture transmission

properties of hydrophilic polyester fabrics have an effect on breathability perception.

Karahan and Eren [13] examined the static liquid absorption properties of towel fabrics produced at different weft and warp setts, different yarn properties and pile heights. They indicated that the towel fabric produced with the two-plied ring carded yarn has higher liquid absorption values than that of the fabric produced rotor yarn. They also found that the increase in weft and warp setts results in a decrease in liquid absorption, and an increase in pile height causes increase liquid absorption.

Kim et al. [14] investigated that different woven and knitted fabrics having high liquid absorption capacity and found that the values of tightness and fiber size are minimum, and the values of thickness and pore size are maximum in the fabrics for optimum absorption behavior.

Long and Hai-Ru [15] show that the liquid transfer is dependent on the absorption properties of the fibers on both faces of the fabric and the difference between these properties.

Özdil et al. [16] researched that the moisture management properties of the knitted fabrics having different cotton yarn counts different twist values. They determined dynamic liquid transport properties of the fabrics with SDL-ATLAS Moisture Management Tester. They revealed that the effects of yarn count and yarn twist coefficient on the moisture management properties were significant, and all the fabrics used in the study have good moisture management capability.

Özkan and Kaplangiray [7] examined that moisture management properties of different blends of wool/polyester fabrics which are used in winter military clothes with MMT test device. They indicated that the moisture management properties improved when the wool fiber diameter decreased and as the percentage of fiber increased, and the overall moisture management value decreased as the yarn count increased and the percentage of polyester fiber increased.

Uyanik [17] determined the liquid moisture management properties of vortex knitted fabrics. For this purpose, the vortex yarns with 19,7 tex obtained different blend ratios by using carded cotton, viscose, modal, silver added polyester (Flexsil-D2^{TM}), polyester, and nylon 6.6 fibers were knitted in two different stitch lengths as tight and loose, and dyed considering fiber types. The results of the study revealed that moisture management properties of vortex knitted fabrics are much affected by fiber types in comparison with fabric tightness. Modal and nylon fibers are very positive in terms of moisture management performance. The vortex yarns having low diameter, high shape values that is more rounded, and high density improve moisture management performance of the knitted fabrics whereas the hairy yarns and higher fabric thickness reduce it.

Wallenberger [18] determined that the most advantageous fiber in terms of comfort is quickly transfer the liquid and dry it in a short time, and a fiber with higher liquid absorption capacity causes wet feeling and comfortless due to the long drying time.

Yüksel and Okur [8] investigated that the relationships between subjective comfort evaluations and fabric characteristics that can be measured objectively, and to evaluate properties associated with comfort of fabrics having different material and structural features. They found that there was a significant correlation between top absorption rate and wetting time measured in MMT and the wet feelings of the subjects.

As seen in the previous works, although there have been some studies in the literature to determine the moisture performance with MMT tester or other devices, no study has been done on the use of knitted terry fabrics. Therefore, it is aimed to present absorbency and other liquid (moisture) performance characteristics of the knitted terry fabrics which are common in garment use in this study with MMT tester.

2. Material and Method

In this study, twelve samples of three different platinum heights as 2.2 mm, 2.5 mm, and 2.8 mm were obtained by using Ne 30 and Ne 24 100% cotton yarns as pile yarns, 70 denier and 90 denier 100% polyester filament yarns as the ground yarn to investigate the moisture management properties of the knitted terry fabrics. Knitted terry fabrics are dyed with the same processes including scouring, dyeing and washing. The physical properties of the fabrics are determined according to the standards TS EN ISO 14971, TS 629, TS EN 12127, and TS 7128 EN ISO 5084, respectively, and the absorption properties are determined with SDL Atlas Moisture Management Tester according to AATCC 195 standard. All measurements and tests were performed under standard atmospheric conditions, and repeated as five times. The production parameters, pile yarn properties measured by Uster Tester 5 device, and fabric properties are given in the Tables 2, 3 and 4, respectively.

Table 2. Production parameters

Ground yarn	70 Td - 90 Td polyester
Pile yarn	Ne 24 – Ne 30 100% cotton
Sinker heights	2.2 mm - 2.5 mm - 2.8 mm
Knitting machine	30 inch, E 20, 44 feeders, Keumyong KM-3SV

Table 3. Pile yarn properties

Yarns	**Ne 30**	**Ne 24**
USTER, %	12.1	11.3
Thin -50%	13	2
Thick +50%	182	107
Neps +200%	251	91
Hairiness, H	7.1	7.7
Tenacity, cN/tex	15.4	18.3
Elongation, %	4.6	5.0
Twist (T/m)	820	733

Table 4. Knitted terry fabric properties

Yarn number		Sinker height (mm)	Stitches/cm		Weight (g/m²)	Thickness (mm)
Ground (Td)	Pile (Ne)		Courses	Wales		
90	30	2.2	12.5	9	214.35	1.58
90	30	2.5	12.5	9	230.87	1.85
90	30	2.8	14	10	259.76	1.94
90	24	2.2	12.5	9	268.48	1.85
90	24	2.5	14	9	286.57	1.88
90	24	2.8	15.5	9.5	331.50	2.16
70	30	2.2	12	9	192.67	1.50
70	30	2.5	13	10	236.73	1.85
70	30	2.8	14	9.5	242.99	1.75
70	24	2.2	12.5	9	240.05	1.69
70	24	2.5	12.5	9	264.33	1.82
70	24	2.8	14.5	10	320.24	2.01

Additionally, the regression tests were made in 0.05 significance level for statistical analysis. The results were given in Table 6.

3. Results and Discussion

The moisture management properties of knitted terry fabrics are given in Table 5.

Table 5. MMT test results of knitted terry fabrics

Ground (Td)	Pile (Ne)	Sinker height (mm)	Wetting time (sec)		Absorption rate (%/sec)		Spreading speed (mm/sec)		OWTC (%)
			Top	Bottom	Top	Bottom	Top	Bottom	
90	30	2.2	50.76	11.87	19.25	52.44	0.11	0.45	639.86
70	30	2.2	34.36	12.31	32.46	46.04	0.20	0.48	310.61
90	24	2.2	52.72	17.18	11.92	23.94	0.32	1.04	741.83
70	24	2.2	20.36	13.97	46.46	14.55	0.27	0.46	387.72
90	30	2.5	31.20	10.18	25.98	39.88	0.28	0.57	403.74
70	30	2.5	61.22	14.31	18.66	83.10	0.08	0.34	641.73
90	24	2.5	47.57	14.31	25.83	47.40	0.13	0.35	629.66
70	24	2.5	41.57	8.76	16.33	20.97	0.17	0.89	751.02
90	30	2.8	61.89	15.38	19.91	54.80	0.08	0.32	726.26
70	30	2.8	57.30	15.47	23.08	50.05	0.12	0.34	685.95
90	24	2.8	43.27	13.57	27.21	37.44	0.15	0.39	605.31
70	24	2.8	42.88	12.60	26.32	34.79	0.13	0.43	591.71

Test results were examined in the subheadings of absorption rate (AR), spreading speed (SS), one way transport capability (OWTC) and moisture management (OMMC) performance.

3.1. Absorption Rate (AR)

The graph of absorption rates of knit towel samples is given in Figure 7. According to graph, the bottom AR are higher than that of the top except sample having 2.2 sinker-70 Td ground yarn-Ne 30 pile yarn. For the fabrics containing 2.2 sinker, the samples having 70 Td ground yarn have higher AR than that of 90 Td ground yarn on the top surface whereas the samples having Ne 30 pile yarn have higher AR than that of Ne 24 pile yarn on the bottom surface. It is seen that the fabrics with 2.5 sinker containing 90 Td ground yarn have higher AR except sample having 70 Td-Ne 30 yarn. The samples with 2.8 sinker have slightly higher AR on the bottom surface than the other samples except sample having 70 Td-Ne 30 yarn. Additionally for the fabrics with 2.8 sinker, the samples containing Ne 24 pile yarn have higher AR on the top surface, on the contrary, reverse tendency is observed on the bottom surface.

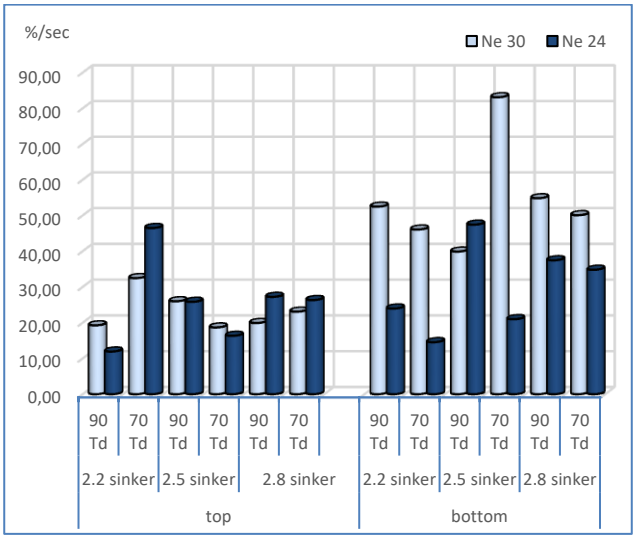

Figure 7. Absorption rate

3.2. Spreading Speed (SS)

The graph showing the spreading speeds of the knitted towel samples is given in Figure 8.

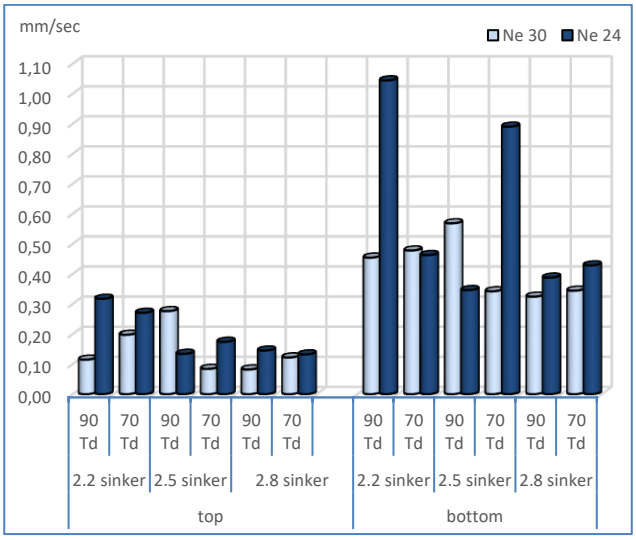

Figure 8. Spreading speed

It is observed from Figure 8 that the bottom SS has higher than top SS for all samples from figure. For the fabrics with 2.2 sinker, the samples having Ne 24 pile yarn have higher SS than the samples having Ne 30 pile yarn on the top surface, whereas SS values of the samples are almost same on the bottom surface except the sample having 90 Td-Ne 24 yarns. The samples of 90 Td-Ne 30 yarns and 70 Td-Ne 24 yarns have higher SS than the other samples in the fabrics with 2.5 sinker. On the other hand, SS values of the samples containing different ground and pile yarns for 2.8 sinker are close to each other.

3.3. One Way Transport Capability (OWTC)

According to Figure 9, the samples with 90Td ground yarn have higher OWTC than the samples with 70 Td ground yarn for the fabrics with 2.2 sinker. Hence the samples having Ne 24 pile yarn have higher OWTC than the samples having Ne 30 pile yarn in these fabrics. On the contrary, the samples with 70 Td ground yarn have higher OWTC than the samples with 90 Td ground yarn for the fabrics with 2.5 sinker whereas OWTC are almost same in the samples having different ground yarn for the fabrics with 2.8 sinker. For the fabrics with 2.5 sinker and 2.8 sinker in terms of the pile yarns, OWTC values of the samples having Ne 24 are higher than that of the samples having Ne 30 in the fabrics with 2.5 sinker whereas the tendency is reverse in the fabrics with 2.8 sinker

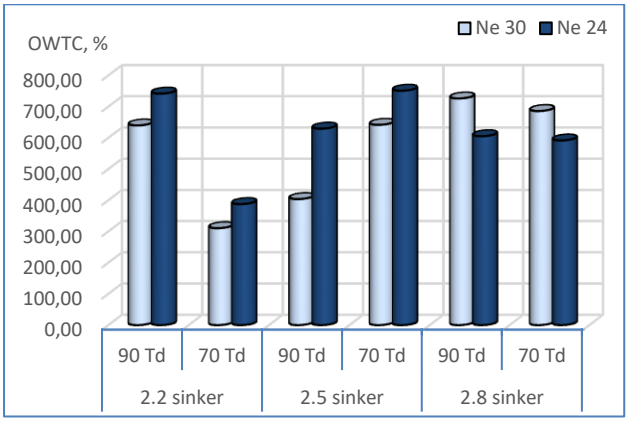

Figure 9. One way transport capability (OWTC)

3.4. Overall Moisture Management Capacity (OMMC)

It is seen from Figure 10 that the samples having Ne 30 pile yarn have higher OMMC than the samples having Ne 24 pile yarn for the fabrics with 2.2 sinker. In the fabrics with 2.5 sinker, the sample containing Ne 30 pile yarn lower OMMC for 90 Td ground yarn, whereas higher OMMC for 70 Td ground yarn. Additionally, OMMC values are same in the samples having Ne 24 pile yarn for the fabrics with 2.5 sinker and all the samples with 2.8 sinker.

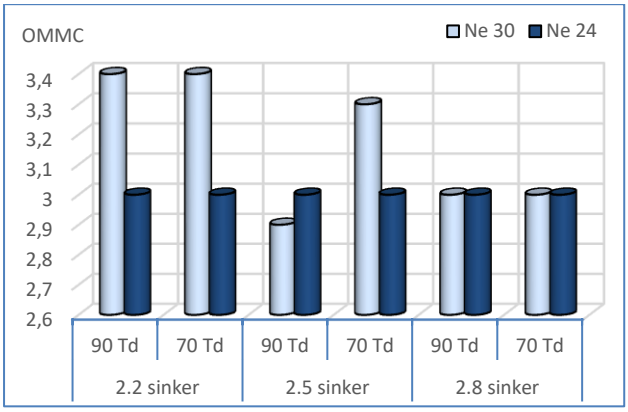

Figure 10. Overall moisture management capacity (OMMC)

Table 6. Regression test results

Factors		Ground yarn		Pile yarn		Pile height	
		t *	Sig. **	t	Sig.	t	Sig.
Absorption rate	Top	-0.181	0.860	0.546	0.599	0.699	0.520
	Bottom	-0.787	0.452	2.155	0.060	-0.162	0.875
Spreading speed	Top	1.504	0.167	0.123	0.905	-0.601	0.563
	Bottom	1.321	0.219	-0.169	0.870	-0.149	0.885
OWTC		0.900	0.392	-0.722	0.489	1.769	0.117
OMMC		1.081	0.308	**3.069**	**0.013**	0.933	0.375

t* Test statistic
Sig.** Significance

According to Table 6, ground yarn and pile height are not effective on the examined moisture management properties. Pile yarn has only effect on OMMC, whereas it has not affect the other properties.

4. Conclusion

As determined in the previous works, it is once again shown that yarn count and pile height have influence on moisture management properties of the fabrics with the study.

The study reveals that bottom absorption rate and spreading speed than that of top for all pile loop knit fabrics. Fabrics with coarse pile yarns (Ne 24) exhibit lower absorbency on the bottom surface than fabrics with fine pile yarns (Ne 30). Fabrics with low sinker height and fine ground yarn have higher top absorption rate whereas fabrics with coarse ground yarn (90 Td) have usually higher bottom absorption rate. The absorption rate values are slightly higher in fabrics with 2.8 sinker.

Fabrics with coarse pile yarn (Ne 24) have higher top spreading speed whereas bottom spreading speed is higher in the fabrics with low sinker height.

OWTC of the fabrics having coarse pile yarn in low sinker height is better, on the contrary, OWTC of the fabrics containing fine pile yarn in high sinker height is better.

As a result, it can be said that moisture management performance (OMMC) is higher in the fabrics having low sinker height, fine ground and pile yarn.

It is suggested that the moisture management performances of pile loop (knitted towel) fabrics should be fully demonstrated by carrying out similar works with different numbers of pile and ground yarns, pile yarns with different raw materials or different pile heights for future studies.

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Review Article

An investigation on auxetic feature and its applications

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ABSTRACT

The technology aims to respond to ever-increasing needs day by day is in a progressing development. One of the basic and most important components of technology is material. Nowadays, as an alternative to conventional engineering materials, multi-functional new generation competitive materials are obtained by adding new features to existing materials or developing new materials in order to meet the demands of the present and future. In this respect, the negative Poisson's ratio (auxetic) materials are one of the most widespread research subjects recently. The auxetic structure and materials, originally found in nature, have been observed to separate from traditional (positive Poisson's ratio) materials with various mechanical properties, mainly deformation mechanisms, thanks to their unique microstructures. In this study, auxetic feature is investigated and researches for adaptation of the auxetic feature to various science and technology fields are compiled.

1. Introduction

Materials have various mechanical properties according to the characteristic of their microstructures. These properties, which guide the behavior of materials, play an important role in many stages from design to manufacturing method and product development. Many of the mechanical behaviors of materials have been expressed numerically with the formulas. The Poisson's ratio, which is one of the most important formulas in engineering, can be defined as the negative ratio of the transverse strain to axial strain [1]. The Poisson's ratio is given by Equation (1)

$$\nu = -\frac{\left(\frac{\Delta y}{y_0}\right)}{\left(\frac{\Delta x}{x_0}\right)} = -\frac{\varepsilon_y}{\varepsilon_x} = -\frac{\varepsilon_{transverse}}{\varepsilon_{axial}} \qquad (1)$$

It's a physical phenomenon known by experiences that conventional materials expand in the direction they are stretched and contract in other directions. In this case, the Poisson's ratio values of conventional materials are considered as positive. However, due to their unique microstructures, some materials and structures which are different from conventional materials, by the way of expanding as they are stretched or contracting as a result of compression, are a continuing research subject. These materials have negative Poisson's ratio values due to the deformation mechanism they exhibit. Materials with negative Poisson's ratio have been called "auxetic" which is a Greek word "auxetikos" meaning "tend to increase". The term "auxetic" was first used in 1991 by Professor Ken Evans [2]. The deformation mechanisms of both auxetic and conventional materials are shown in Figure 1. Researches that have been conducted over 30 years include various purposes such as the understanding of the mechanism leading to auxetic behavior, designing and production of auxetic materials and examination and development of mechanical properties of auxetic materials [3]. In this study, the auxetic feature is investigated and the researches on the adaptation of auxetic feature to technology are compiled.

2. Auxetic Structures and Materials

Auxetic behavior is the feature that independent from the dimensional scale, so can be observed in various sizes

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from molecular level to bulk structures (Figure 2) [4].

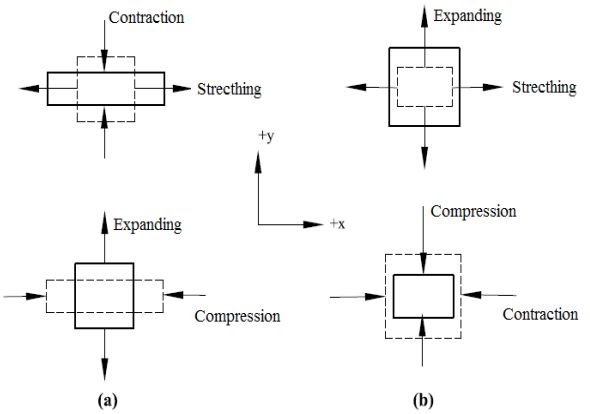

Figure 1. Deformation mechanisms of (a) a conventional and (b) an auxetic structure [5]

The first natural material at the molecular level being observed to exhibit auxetic behavior was cubic monocrystalline iron pyrite (iron sulphide) (Poisson's ratio value $\nu = -0.14$), discovered at the beginning of 1900's. It was observed that iron pyrite exhibits auxetic behavior due to its twin crystal structure [6]. Ledbetter et al. [7] have found that YBa2Cu3O7 (yttrium barium copper oxide) exhibits auxetic behaviour. Milstein et al. [8], then Baughman et al. [9] reported that cubic crystal structures exhibit auxetic behavior at a rate of 69% on the (110) plane. Other natural auxetic materials which have been discovered through researches and take place in literature are thermal graphite [10], rocks with micro cracks in the structure [11,12], arsenic with single crystalline structure [13] and cadmium [14], α-cristobalite silica crystal with multi-crystalline structure [15]. There are also examples of biological structures in which the auxetic feature is observed such as cancellous bone in human [16], cow teat skin [17], cat skin [18] and salamander skin [19].

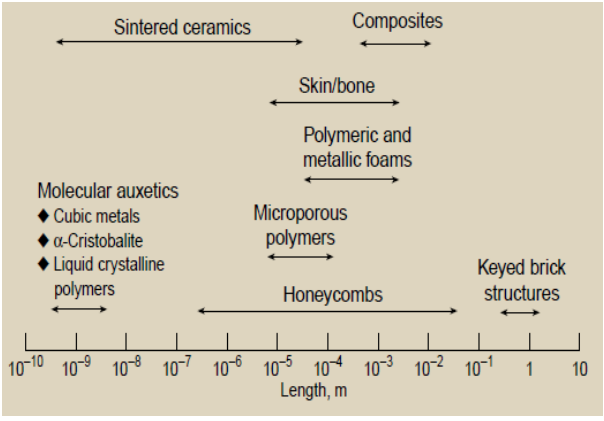

Figure 2. Auxetic structures and materials in various levels [4]

The first designed structure which auxetic deformation mechanism obtained was a 2D anisotropic "re-entrant honeycomb" model (Figure 3). The structure designed by Gibson et al. [20] was also manufactured using silicon-rubber and aluminum.

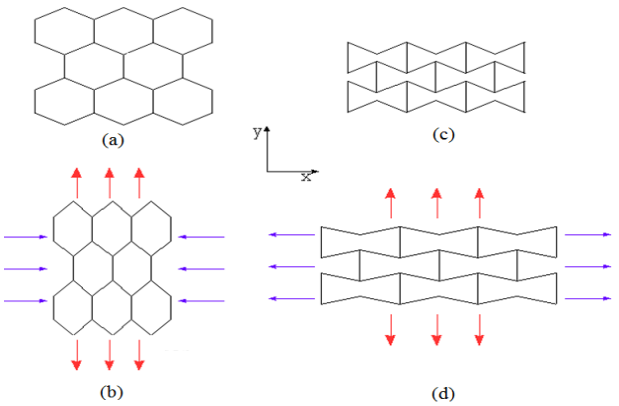

Figure 3. Conventional honeycomb model (a) in the free state (b) in the deformation state and auxetic anisotropic honeycomb model (c) in the free state (d) in the deformation state [20]

Almgren [21] purposed a three-dimensional re-entrant honeycomb model. It was observed that shear stress occurred in plane in case of axial stretching or compressing. In this study, springs were placed between the collars on the vertical beams of the honeycomb structure. Very large shear stress ($G = \infty$) was obtained with this structure for Poisson's ratio$\nu = -1$. The model is elastically isotropic (Figure 4).

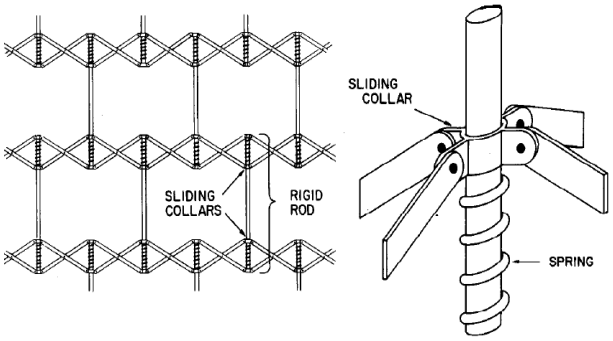

Figure 4. Auxetic isotropic honeycomb model [21]

Lakes [22] successfully produced the first auxetic open-pore isotropic polyurethane foam with his own method. Conventional open-pore, low-density polyester foam was compressed volumetrically to make pores of the foam re-entrant. Later, the foam was heated to a temperature slightly above its softening temperature after placing to pattern. Finally, the foam was allowed to cool at room temperature. Through experiments with different values of production parameters, negative Poisson's ratio value ($\nu = -0,7$) was obtained. Auxetic foam was observed to be more flexible than conventional foam. Figure 5 shows the microstructures of both conventional and auxetic foams.

Friis et al. [23] produced auxetic foams using conventional open-pore thermoplastic (polyester urethane), thermoset (silicone rubber) and copper foam through the method developed by Lakes. They observed that the elasticity modulus of auxetic foams produced was

lower than that of conventional foams.

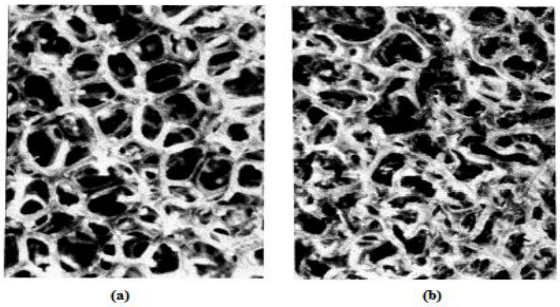

Figure 5. Microstructures of (a) a conventional foam and (b) auxetic foam [22]

Caddock et al. [24] produced an expanded form of polytetrafluoroethylene (ePTFE), a microporous anisotropic auxetic polymer (Figure 6). The Poisson's ratio values of auxetic ePTFE varied up to $\nu = -12$.

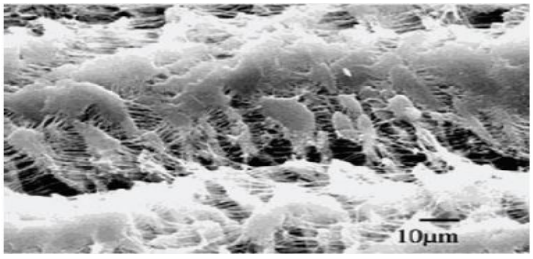

Figure 6. Microstructure of ePTFE in expanded form with auxetic feature [24]

Evans et al. [25] designed a 2–dimensional model to observe the mechanism that leads to auxetic behavior in ePTFE. The designed model was compatible with the experimental results (Figure 7).

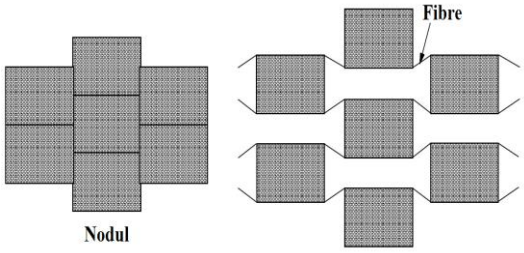

Figure 7. 2–dimensional model of auxetic ePTFE [25]

Choi et al. [26] studied on parameters affecting auxetic foam production. In their study, parameters such as material type, temperature, process time, humidity, permanent volumetric compression ratio, relative density and pore sizes were investigated through experiments with industrial polymer foams (Scott foam and gray polyurethane-polyester foam) which have the same density. In addition, they revealed the relation between permanent volumetric compression ratio factor–Poisson's ratio and elasticity modulus–shear modulus. They also observed that for the auxetic foams they obtained, there was a direct proportional relation between the applied permanent volumetric compression ratio and fracture toughness. In the auxetic foam materials they produced, they obtained $\nu = -0.7$ Poisson's ratio value. Also for another study, they obtained Poisson's ratio of $\nu = -0.8$ with re–entrant porous copper foams [27]. Choi et al. [28] compared the results of numerical analysis performed on the 3-dimensional ideal foam cell model (Figure 8) and the results of experimental studies with conventional and auxetic open-pore foam materials previously produced. The generated 3D model was found to be successful in explaining the deformation mechanism and mechanical behaviors of the both foams.

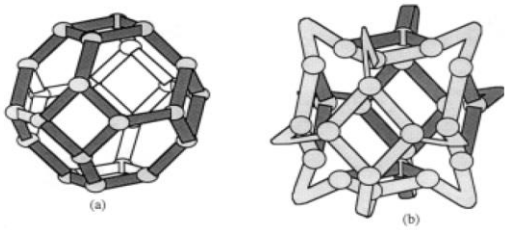

Figure 8. (a)An ideal conventional foam cell model, (b) an ideal auxetic foam cell model [28]

He et al. [29] designed a model of molecular–level structure to adapt auxetic feature to polymer materials. The proposed model is formed by placing rigid rod–shaped molecules at a distance on the fluid crystalline polymer chain with linking elements. In unloaded state, the rigid rod-like molecules oriented parallel to the chain of the polymer they are on (Figure 9(a)), come to the perpendicular position to the polymer chain by rotating around their centers with stretching (Figure 9(b)). Auxetic feature has been observed with this mechanism. In this model, the dimensions of the rigid rod molecules and the length of the fluid crystalline polymer chain are parameters that affect the auxetic feature.

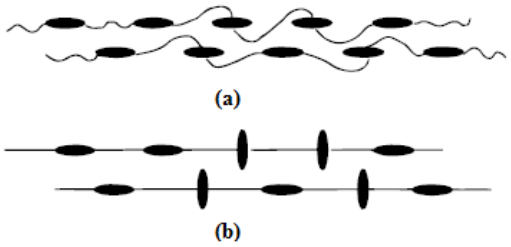

Figure 9. Fluid-crystalline polymer chain model of auxetic polymers (a) before stretching and (b) after stretching [29]

Larsen et al. [30] observed auxetic behavior with both 2–dimensional numerical model formed from arrowhead unit cells (Figure 10), generated through the numerical topology optimization method, and a prototype they produced. The prototype of this structure was fabricated through silicon surface micromachining technique. With the numerical model, the Poisson's ratio $\nu = -0.8$ was obtained. Also, for the prototype fabricated by through silicon surface micromachining technique, the Poisson's

ratio $\nu = -0.92$ was obtained.

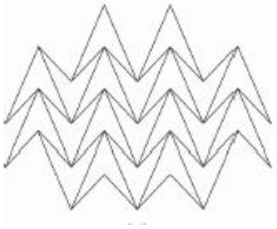

Figure 10. Structure of a unit cell with periodic arrowheads in which auxetic behavior observed [30]

Prall et al. [31] investigated the relationship between the geometric structure and mechanical properties of the 2–dimensional hexagonal asymmetric model (Figure 11) they designed with numerical and experimental studies. For this model, they obtained the Poisson's ratio $\nu = -1$ in plane regardless of strain.

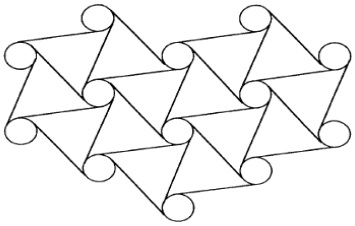

Figure 11. Auxetic 2D asymmetric hexagonal model [31]

Smith et al. [32] developed a 2–dimensional numerical model to help to evaluate the strain-dependent Poisson's ratio values and stress–strain behavior of the first polyurethane auxetic foam (Figure 12). Compared with the previously generated honeycomb model, for this model, results of numerical analysis are found to be more compatible with experimental results with auxetic foam.

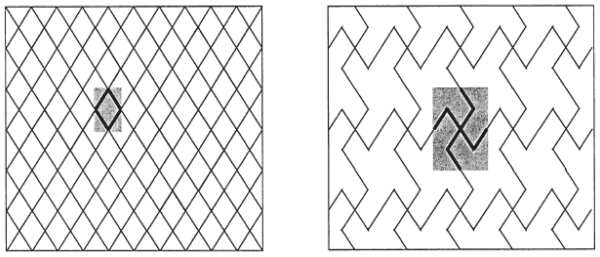

Figure 12. Model developed to explain and evaluate the experimental results of polyurethane auxetic foam [32]

Grima et al. designed 2–dimensional isotropic microstructure models consist of rigid square cells [33], rectangular cells [34] and triangular cells [35] to examine and explain the deformation mechanism of such structures as, crystalline inorganic materials [33], silica, zeolites, fluid crystalline polymers [34], the ABW and JBW zeolites [35], at which auxetic behavior was observed (Figure 13).

Tatlıer et al. examined the adaptability of the auxetic feature to fiber network structures. They investigated the effects of the structural parameters of the fiber network

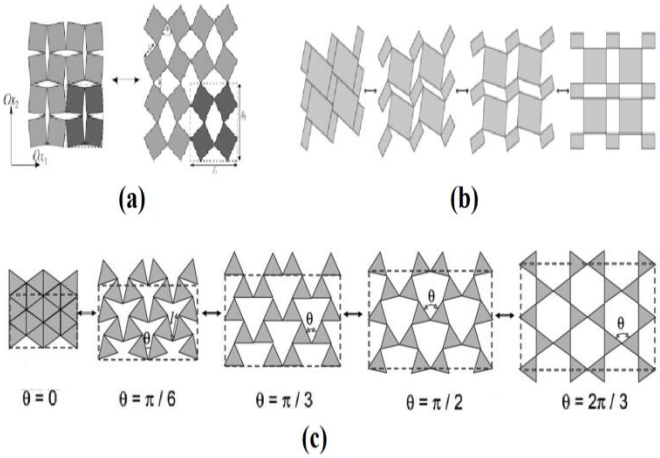

Figure 13. The auxetic microstructure models consist of (a) moving square cells, (b) rotating triangular cells and (c) rectangular cells [33–35]

and the applied axial compression, on auxetic feature with numerical method [36,37]. Also, experimental results obtained from tensile tests, applied to a pre–compressed stainless steel fiber network, provided consistency with numerical analysis' results [36].

Since negative Poisson's ratio has also emerged at nanostructures such as multi–layer orthorhombic arsenic [38], black phosphorus [39], single–layer graphene [40] and single–layer molybdenum disulphide (MoS_2) [41], recent studies have addressed to the researching and development of auxetic engineering nanomaterials. One of the determining features governing the mechanical properties of nanomaterials is their inherent large surface–to–volume ratio (in 3D), or their large edge–to–area ratio (in 2D), which causes surface stress [42]. Results obtained from studies on designing such auxetic nanomaterials as nanoscale metal (001) plates [43], metal [100] nanowires and nanotubes [44] have been verified this theory.

Alderson et al. [45] developed 3 different analytical molecular constructions consisting of SiO_4 tetrahedron molecules for investigating into deformation mechanisms and mechanical properties of α–cristobalite. The model incorporating tetrahedral a–axes rotation to act concurrently with both tetrahedral c–axes rotation and dilation exactly fit with the experimental results [15].

Valente et al. [46], for the first time, researched into the optical properties of micro and nanoscale auxetic plasmonic metamaterials (planar re-entrant honeycombs with Poisson ratio between –0.3 and –0.5) they fabricated by nanomembrane technology.

3. Auxetic Feature and Its Applications

The most distinguishing characteristic of auxetic structures and materials is the mechanical behaviour, which is different from the conventional engineering

materials due to the negative Poisson's ratio. In addition, negative Poisson's ratio accompanies many mechanical features through auxetic structure and materials. Thus, various application areas for auxetic structures and materials have been emerged.

According to the elasticity theory, the relationship between elasticity modulus (E), shear modulus (G), volume modulus (K) and Poisson's ratio (ν) of the parameters that play a role in determining the mechanical properties of isotropic materials is like in Equation (2) and Equation (3) [38--47].

$$G = \frac{E}{2(1+\nu)} \tag{2}$$

$$K = \frac{E}{3(1-2\nu)} \tag{3}$$

3–dimensional isotropic, linear elastic materials have a theoretical Poisson's ratio in the range of $-1 \leq \nu \leq 1$ and 2–dimensional isotropic, linear elastic materials have a theoretical Poisson's ratio in the range of $-1 \leq \nu \leq 0.5$ [48]. Considering Equation (2) and Equation (3), it can be seen that the bulk modulus value is much larger than the shear modulus value (G << K) for the materials with Poisson's ratio of 0.5 or close to this value. However, it can be seen that the value of the shear modulus for the materials with a Poisson's ratio of –1 and close to this value is much larger than the volume modulus value (K << G). For example, magnox nuclear reactor built in England in the 1950s, designed so that the reactors can move freely in order to ensure the safety of the reactor against the effects of the horizontal components of the loads (shear stress) that may occur because of earthquake, thermal expansion/contraction, etc. (Figure 14). This structure was regarded as one of the first auxetic structures, since the highest shear stress carrying capacity for the structure would be the case for $\nu = -1$ [49].

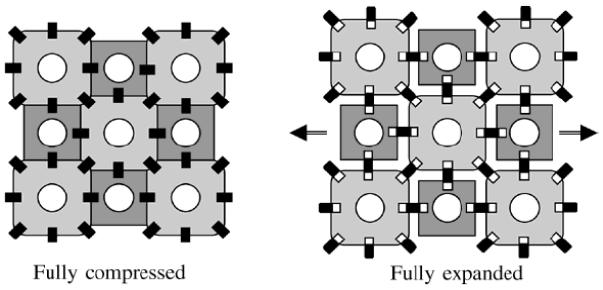

Figure 14. Structure of magnox reactor [49]

For auxetic foams, it has been demonstrated with experiments that fracture toughness is a function of the permanent volumetric compression ratio [48]. As a result of experimental works by Choi et al. [26] has shown that auxetic foam has better fracture toughness properties when compared to conventional polyurethane–polyester foam. Auxetic materials also have high crack resistance. If there is a crack in the auxetic material, so the material will expand as it stretched and close the crack [48].

The materials resists to plastic deformation due to the hardness they have. The measure of this resistance is the degree of indentation on the surface of material when the pressure applied to the material. The indentation resistance (rigidity) for isotropic materials is given in Eq. (4) [49].

$$\mathbf{H} \propto \left[\frac{\mathbf{E}}{(\mathbf{1}-\boldsymbol{\nu})^{\mathbf{2}}}\right]^{\boldsymbol{\gamma}} \tag{4}$$

Accordingly, the indentation resistance for Poisson's ratio of –1 and 1 has the highest value. However, considering that the Poisson's ratio value for isotropic materials cannot exceed 0.5, the indentation resistance will have the highest value for the Poisson's ratio values of –1 or closest. Thus, given the fact that auxetic materials tend to contraction in all directions when compressed, the density and therefore the indentation resistance at the point where the compression is applied will increase. Conversely, in non-auxetic materials, the density decreases so does the indentation resistance at the point where the pressure is applied (Figure 15) [49].

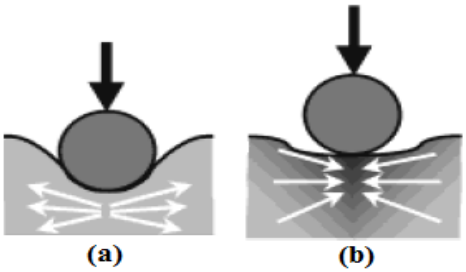

Figure 15. Indentation resistance in (a) conventional and (b) auxetic materials [49]

Smith et al. [50] observed that auxetic foams, regardless of bulk density and bulk modulus, had better indentation resistance than conventional foams. In addition, Alderson et al. [51] have found that, for lower loads, the auxetic UHMWPE (ultra-high molecular weight polyethylene) has better indentation resistance compared to conventional UHMWPE.

Compared to conventional materials, auxetic materials have superior ability to absorb energy (such as acoustic, ultrasonic, vibration, impact) [48]. Scarpa et al. observed that auxetic foams have better sound absorption [52] and better dynamic crushing resistance properties [53] than non-auxetic foams. Howell et al. [54] tested of sound absorption capability of auxetic polyurethane auxetic foam for a frequency range of 100–1600 Hz. Alderson et al. [55] conducted experimental studies for comparison of sound absorption capability of auxetic, compacted and

sintered and conventional UHMWPE's at ultrasonic frequencies. It was concluded that sound absorption ability was enhanced along with degree of auxeticity. Scarpa et al. [56] studied on utilizing the auxetic feature to reduce the effects of especially human exposure to hand-arm vibration. They proposed the idea of anti-vibration gloves made from auxetic polyurethane (PU) foams. Transmissibility tests, conducted to determine the anti-vibration characteristics of auxetic polyurethane (PU) foams, also determine the foam manufacturing parameters. Within the tests, transmissibility was found to be greater than 1 in the frequency range from 10 to 31.5 Hz, while it was less than 1 for the frequencies greater than 31.5 Hz. Applicability of auxetic feature to vibration case has been satisfied with some structures reinforced with auxetic materials, like sandwich composites embedded with auxetic layers [57], anti-tetrachiral honeycomb structure with embedded metal rubber particles [58] etc. Lira et. al. [59] designed, manufactured and tested the auxetic band-graded core model in order to provide a decrease of the dynamic modal displacements and the first three natural frequencies within the admissible frequency range and reduction of the total mass (by 35%) of the aero engine fan blades.

Hook et al. [60] introduced the auxetic helical yarn, a multifilament structure consisting of a relatively thicker, low-stiffness core filament wrapped around by a narrower and stiffer one, both of which are non–auxetic. In case of longitudinal stretching, the stiffer filament straightens while the softer core wrap around it, and the structure thickens (Figure 16). Auxetic effect can be observed in this way. Sloan et al. [61] investigated into the effects of the geometric parameters of filaments on the mechanical characterization of auxetic helical yarn, experimentally. They stated that the starting wrap angle had the major effect on auxetic behavior of the structure. Besides, the diameter ratio of wrap to core filaments and the filaments' inherent Poisson's ratio were found to be related to auxetic performance. The other products, such as low modulus auxetic composites [62] and blast-proof curtains [63] also have been developed by utilizing inherently auxetic helical yarn structure.

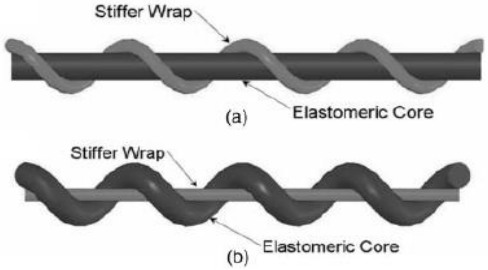

Figure 16. Structure of auxetic helical yarn in (a) unstretched, (b) stretched status [60]

Ugbolue et al. [64] proposed a novel structural model similar to the auxetic helical yarn. This structure consisted of wales of chain and inlaid yarns. The wales, low-stiffnes thicker filaments, are knitted from open loops and the high-stiffness filament is inlaid around the underlap loops (Figure 17).

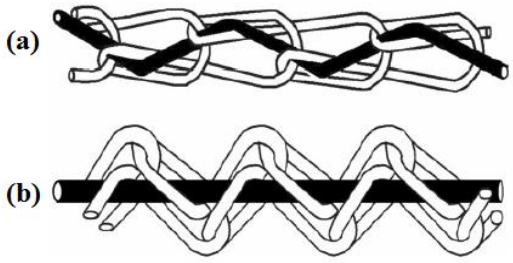

Figure 17. Structure of warp knit consisted of wales of chain and inlaid yarns (a) unstretched, (b) stretched status [64]

The auxetic feature can be employed for various filtration processes (Figure 18). When porous auxetic filtering material is stretched, it enlarges so do the pores. Thus, it can be avoided of pressure increase in the filter and efficiency degradations due to clogging of the pores of filters [65]. Also, breathable fabrics can be produced by utilizing this property of porous auxetic structures. Adjustable pore size level can facilitate air circulation. This feature can be utilized in sportswear where comfort is important [3].

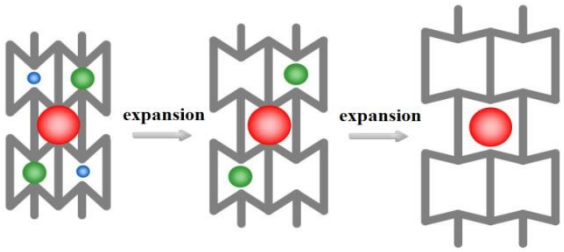

Figure 18. Smart filtering with auxetic feature [66]

Conventional structures and materials take a shape like "saddle" (anticlastic) when they are forced to bend, while auxetic structures and materials have been observed to become dome-shaped (synclastic) (Figure 19). This property can be used in the aerospace industry for the design and production of the nose cone parts and wing panels of air vehicles [49].

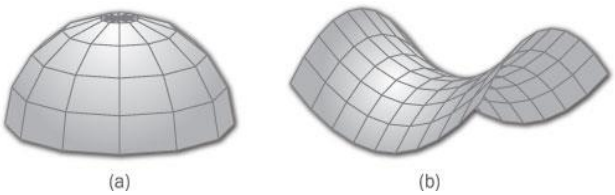

Figure 19. (a) Dome-shaped (synclastic) form of auxetic materials and (b) saddle-shaped (anticlastic) form of conventional materials [67]

Auxetic structures and materials are used in a variety of

applications in the biomedical field, also. Flexible auxetic (ePTFE) vessel dilators used in surgeries like angioplasty, suture anchors, smart bandages, artificial muscles and blood vessels [49], polymeric bone stent for tubular fractures [68] are some of the examples (Figure 20).

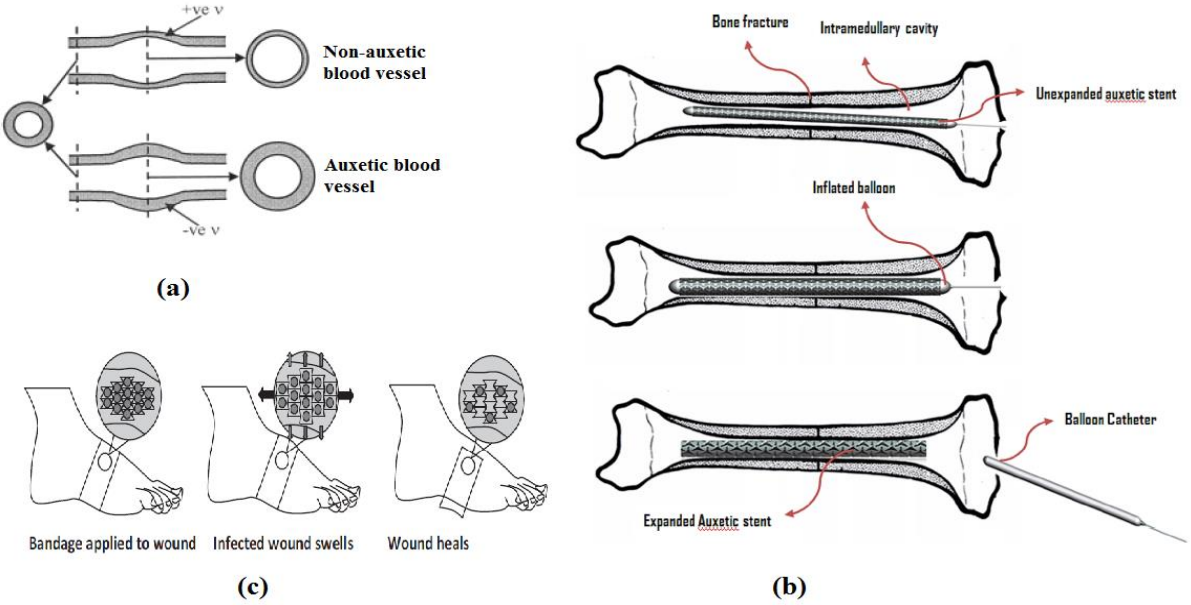

Figure 20. **(a)** Non-auxetic and auxetic blood vessels [49], **(b)** polymeric bone stent for tubular fractures [68], **(c)** smart bandages [69]

4. Discussions

The Poisson's ratio, one of the equations widely used in engineering, expresses how materials respond as deformation to the applied loadings. Materials with positive Poisson's ratio contract laterally while elongate in longitudinal direction. However, auxetic materials and structures exhibit an expansion behavior due to stretching or exhibit contraction with compression, as well. Technology, keep developing to increase quality of life, ensure and maintain life safety, needs better materials than that are today's. These materials are classified as multifunctional, smart materials. Recently, auxetic materials were included in this class. In view of the negative Poisson's ratio, primarily due to their unusual deformation mechanism and mechanical properties, auxetic structures and materials can be used as a subsidiary or alternative to conventional materials.

Compared to conventional materials with the same modulus of elasticity, some mechanical properties of auxetic materials have been observed to be superior. Some of them are;

- increased planar strain resistance [70],
- increased indentation resistance [70],
- increased shear modulus [71],
- increased fracture toughness [72],
- better energy absorption capacity and superior acoustic properties [73],
- controllable porosity-permeability [65],
- dome-shaped (synclastic) bending [74]

The auxetic feature was first discovered in nature in the early twentieth century. However, auxetic materials had not drawn attention until the first isotropic auxetic foam was produced from open-pored conventional foam by Lakes in 1987. Then, various investigations on auxetic properties were made, various auxetic structures and materials were discovered, synthesized and produced. In Available auxetic structures and materials with various application fields are demonstrated in Table 1 [48].

The auxetic feature can be observed due to the porous structure in the materials. It was reported that the auxetic feature might not be able to be encountered in materials with less than 40% porosity, except for natural auxetic structures and materials [75]. High porosity, while making the auxetic property noticeable, causes a decrease in material density and restricts the use of auxetic materials in applications where high strength is required. This limitation can be overcome by the production of reinforced composite materials with auxetic fibers or honeycomb structures, layers etc. [76].

5. Conclusions

Studies have been conducted to develop for such better materials as smart materials, multi-functional materials etc. for the future's requirements. Novel classes of materials have been achieved by such methods as modifying, reverse engineering and discovery of intrinsically different kind of materials. As being one these, an outstanding kind of material, the auxetics,

despite being already discovered first in nature, hadn't drawn much attention until the first auxetic polyurethane foam was produced. By definition, the term "auxetic", which applies to the Poisson's ratio, describes a deformation behavior that exhibits expanding while stretched axially or exhibits contraction with compression in a direction, in contrast to materials with a positive Poisson's ratio. Auxetic behavior is a size-independent feature. The stimulant factor of auxetic behavior is the unique microstructure. Based on this, a variety of microstructural models have been designed to achieve the auxetic behavior. As the researches have continued, variety of outstanding properties accompanied auxetic behavior have emerged, such as higher shear modulus – lower volume modulus, increased planar strain crack resistance, higher stiffness resistance, higher fracture toughness, greater energy absorption capacity, superior acoustic properties, a controllable porosity-permeability and the ability to take a shape like dome-shape (synclastic) in case of bending, when comparing auxetic polymeric materials with those of non–auxetic with the same modulus of elasticity. However, auxetic materials have lower modulus of elasticity than their conventional counterparts due to their porous structure. For this reason, auxetic materials are not suitable enough for the applications that require strength. This limitation can be overcome by improving design of microstructures, or by adaptation of auxetic feature to the conventional structures and materials which are stiffer.

Table 1. Various applications for auxetic materials [48]

Application area	***Applications***
Industry	Reinforcement fibers, air filter, cord and rope, gaskets, fishing nets, rivets, seat belts, vehicle cushions, earphone cushions, shock absorbers and sound dampers
Aeronautics and space	Wing panels, nose cones of aircrafts, curved body parts
Protection	Helmets, bulletproof vests, knee and elbow protectors, gloves, protective clothing, vehicle bumpers, explosion-proof curtains
Biomedical	Bandage, wound pressure pad, drug release, muscle/ligament anchors, dental floss, artificial blood vessel, artificial skin, surgical sutures
Sensors and actuators	Hydrophone, miniaturized sensors, piezoelectric devices
Textiles	Functional fabrics, auxetic fibers, color-change straps and fabrics, threads, yarns

Nomenclature

E : Modulus of elasticity
P : Modulus of shear
H : Hertzian pressure
K : Bulk modulus
Δx : Displacement in direction of x axis
Δy : Displacement in direction of y axis
ε_x : Strain in direction of x axis (axial strain)
ε_y : Strain in direction of y axis (transverse strain)
ν : Poisson's ratio
γ : Hertzian pressure constant

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Review Article

Actions to be taken to prevent negative consequences in the workplace during emergencies

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ABSTRACT

Occupational health and safety related to the work done in workplaces in general people full body health and safety provision. In our country, the occupational health and safety risk assessment analysis moral, legal, and indirect costs has become crucial. Located in the workplace or identification of hazards from outside intrusion, it turned into a risk of danger that led to the factors analyzed by ranking of the risks arising from the dangers with and control measures will be utilized for the purposes of risk assessment and analysis work required. These occupational accidents are a problem that must be resolved as a country reality. Any work that does not have security and supervision issues an accident invitation. Today, worker health and work safety remain a problem that needs to be resolved. In this study, occupational health and safety measures and interventions to be taken against emergencies are described. Emergency action plans will identify emergency situations, such as risk assessments, the likelihood of fires, the probability of explosion from hazardous chemical substances, situations requiring first aid and evacuation, natural disasters and sabotage probabilities, starting from the installation phase for all workplaces. It is prepared by following the revision stages of the contingency plans by taking the many preventive and limiting measures to prevent their adverse effects, determining the teams to be assigned, setting up the intervention to be urgently urgent and establishing the evacuation methods of employees, documentation, exercises and omissions.

1. Introduction

Emergency means that the employees of the enterprise, employees of another company in the business are not liable for any loss or damage to the premises of the enterprise or of any other facility or residential property near the premises [1-4]. It halts the production of the workplace in whole or in part, harms the workplace or the natural environment, unplanned events which give harms [5-8]. These are caused by damage. They are fire, earthquake, flood or flood, storm, earthquake, heavy rain-snowfall, extreme heat-cold, epidemic disease, work accident, production accident, chemical accident, explosive and explosive accident, system collapse, computer system collapse, mass food poisoning, traffic accidents, anarchy and terrorism, sabotage, mobilization and radiation accidents [9-12]. In these emergencies, information on the actions and actions to be taken in order to avoid negative consequences and Emergency Action Plans for all actions taken and emergency action plans for the actions taken are called [13-16]. It is expressed what needs to be done in emergency action plans. These are save and protect equipment and records for similar processes. That can cause emergency situations and to prevent the accident and damage caused by accidents and injuries, to save and recover accident victims, to salvage employees, to reduce damage to goods and materials, to prevent spreading and control events, experts to provide the necessary information [17-20]. The following situations require immediate intervention by the management and intervention including the necessary resources to control and end the incident [21-24]. These are; fire, bombing, sabotage, terrorism, war, as serious incidents and deaths, major damage to property, serious damage outside the field, threats to business continuity, company safety measures, serious environmental damage. The consequences of the potential hazards described above, earthquake, flood and flood, storm, explosion, equipment breakdown or becoming unusable which can occur in case of work accidents [25-28].

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There is no enough study in the literature about preparing emergency plans. In this study, it is proposed how to prepare the contingency plans by filling this gap in the literature.

2. Preparation of Emergency Plans and Transferred To Employees

Emergency action plans consist of the creation of a team of experts for planning, the analysis and evaluation of the possible hazards and risks, the preparation of the obtained Emergency Plans and the testing and putting into force the prepared plans [29-31]. In Figure 1, emergency planning is shown.

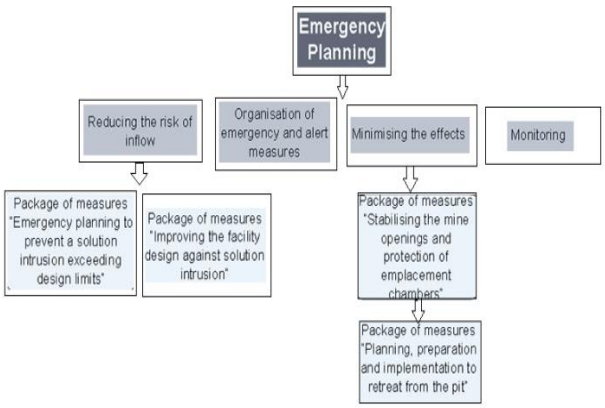

Figure 1. Emergency planning [32].

Emergency action plans will identify emergency situations, such as risk assessments, the likelihood of fires, the probability of explosion from hazardous chemical substances, situations requiring first aid and evacuation, natural disasters and sabotage probabilities, starting from the installation phase for all workplaces [33-36]. They are prepared by following the revision stages of the contingency plans by taking many precautions and limiting measures to prevent their adverse effects [37]. They are also determining the teams to be assigned, setting up the intervention to be urgently urgent and establishing the evacuation methods of employees, documentation, exercises and omissions [38-40]. What are the risks in the workplace with emergency plans [41]. What are the prospects of explosion from dangerous chemical substances, situations requiring first aid and evacuation, natural disasters and sabotage probabilities [42]. What are the preventive and limiting measures for their adverse effects, search, rescue and evacuation, all employees of the workplace should be informed about who is assigned to them [43]. In addition, employees newly recruited should be provided with information on emergency plans in addition to occupational health and safety trainings [44]. Employees specially trained in the topics of the emergency actions should be trained in the tasks with special training to be carried out by the occupational safety specialist or the workplace physician. In enterprises, periodical annual training programs should be prepared and trainings should be repeated and new information about incomplete situations should be informed. Emergency plans should be updated every six years in low-risk businesses, every four years in hazardous businesses, and every two years in very hazardous businesses.

3. Measures and Exercises

The employer, the workplace specialist and the workplace physician should take all necessary precautions to prevent or mitigate any material or moral damages that may be caused by all identified risks and emergencies. The employer, the workplace specialist and the workplace physician must make measurements in order to avoid the material and moral adverse effects of all these risks and emergencies and these measurements should be made together with experts based on risk protection principles and collective protection. In Figure 2, preparedness cycle is shown.

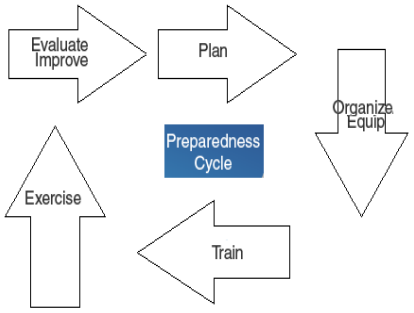

Figure 2. Preparedness cycle [45].

Exercises should be carried out in the workplace to ensure that the emergency plan prepared by the employer, the workplace specialist and the workplace physician is followed by individual steps and is feasible and that all personnel will know what to do [46]. As far as possible, the reality of life should be recreated with the necessary corrective and preventive action, with the implementation steps of the emergency plan passing through the supervised eye, creating a near-immediate emergency [47]. Involvement in these exercises should be encouraged in other institutions, apart from the operation. In these exercises, the corrective actions to be made in accordance with the experiences gained in terms of missing deficiencies should be reported with a date and should be repeated periodically every year [48].

4. Education of Emergency Equipment and Employees

The employer, workplace specialist and workplace physician in the workplace;

- The fire intervention team in charge of interfering with the fire to prevent the growth of the fire and putting it out,
- Rescue team in charge of rescue of life and property in fire and other emergency situations,
- First aid and treatment team assigned to first aid to those who are injured or ill in the fire,

- The security team in charge of protecting the recovered goods and documents to prevent panic and confusion arising in the fire,
- A gas leak and electrical control team with the task of preventing gas leakage and electrical leakage,
- A team of helpers and escorts to assist and assist the saved,

at least six teams must be established. Figure 3 shows an emergency team.

Figure 3. Emergency team [49].

Each team must have a team leader who is the deputy assistant to implement internal regulations. All emergency crews and employees;

- What are the risks in the workplace with emergency plans,
- Fire and explosion possibilities arising from chemical substances,
- Situations requiring first aid and evacuation,
- The possibility of natural disasters and sabotage is to prevent and limit the adverse effects of these,
- Search, rescue and evacuation,
- Fire fighting,
- Who are the people assigned to first aid

information training should be given. Employees specifically involved in emergency actions should be trained with special training to be carried out by a work safety specialist or workplace physician. Periodic annual training programs should be prepared in the enterprises and the trainings given to the employees should be repeated.

5. Emergency Equipment

Nothing is stated in the law or in the regulation as to what the emergency equipment is. The assignment and responsibility for selecting the appropriate equipment is left to the employer. The employer needs to be very different in the equipment to be provided that the chemical and physical conditions are different in the different business lines carried out by the employer. The employer is obliged to determine the appropriate equipment according to the chemical and physical conditions of the workplace together with the experts and to provide them to the support staff. These are generally; body protectors, foot protectors, traffic equipments, environmental safety and warning signs, electrical equipments, fire protection equipments, fire protection equipments, fire protection equipments, fire extinguishers, fire extinguishers, fire extinguishers, fire extinguishers, fire extinguishers, fire protection equipment, emergency lighting, emergency lighting, power supply, escape route plans, shelters, critical isolation valves, switches, circuit breakers, fire extinguishing equipment, communication systems, work glove, ax, hammer, bobbin, business glove, dried food, water, clothes, walking shoes, shovel, shovel, hammer, nail, screwdriver, jack, plastic coating roll, rope coil, wire coil, tent, tarpaulin, sock, space map, fire extinguisher, whistle, compass, cap, torch, battery, light bar, match, small It can be expressed as small radio, wound band, surgical glove, mask, single bandage, butterfly bandage, gauze, cotton, adhesive tape, sterilized bandage, broken material, bleach, thermometer, first aid handbook and others.

6. Preventing Great Industrial Injuries

Relevant legislation is about Emergency Plans in Articles 13 and 14 of the Fourth Section of Regulation on the Prevention and Reduction of Major Industrial Accidents published in the Official Gazette dated 30.12.2013 and numbered 28867 [50]. These;

Article 13: (1) The operator of a higher-level entity shall prepare or prepare an internal emergency plan, taking into account the information in the form and the form in the notification to be issued pursuant to paragraph 12 of this Article, provided that it contains at least the information specified in Annex 4, Part 1 and Part 2.

(2) The operator shall send the internal emergency plan to the Ministry of Environment and Urban Planning within thirty (30) business days of notification of the safety report regarding the content and sufficiency of the safety report. If the emergency plan of the organization is not available to the Ministry of Environment and Urbanization for the period specified, it is assumed that there is no internal emergency plan.

(3) The operator shall be responsible for the establishment of the internal emergency plan in the first paragraph of the 17th Article, the units in charge of the emergency service, the relevant Governorate, the Organized Industrial Zone Directorate in case the organization is located in the Organized Industrial Zone, he exchanges information and opinions with the Industrial Zone Directorate of Business.

(4) If the possibility of coastal and / or marine pollution is foreseen after a possible loss of control in the establishment, the Law on Compensation Principles of Intervention and Losses in Emergency Situations in the Contamination of Oil and Other Harmful Matters of the Sea Environment published in the Official Gazette dated 21/10/2006 and numbered 26326 Coastal emergency response plans approved in accordance with paragraph 3

of Article 23 of the Implementing Regulation are only valid for interfering with coastal and marine pollution. Establishments specify the subject matter in their internal emergency plans.

(5) Internal emergency plans are examined by the Ministry of Environment and Urban Planning in terms of content and competence. Examination of contingency plans in terms of content and sufficiency; a) An examination of the adequacy of the emergency measures, whether the internal emergency plan is in conformity with the form to be issued pursuant to paragraph 12 of this Article, and whether there is at least the minimum information required in the internal emergency plan for the establishment according to the said notification, b) Performed without supervision.

(6) It is essential that the information specified in the internal emergency plan reflects the established situation and the operator is responsible for the correctness of this information. The examination of the content and adequacy of the internal emergency plan is made assuming that the information provided by the operator is correct.

(7) Operator: a) If incomplete information is found in the internal emergency plan, the updated internal emergency plan or the internal emergency plan, it shall send the missing information to the Ministry of Environment and Urbanization in writing and in wet signed form and as four digital copies of this copy. b) Notify the fact that the internal emergency plan is sufficient by the Ministry of Environment and Urban Planning and then load it on the notification and registration system within ten business days.

(8) Ministry of Environment and Urban Planning; in the case where the whole of the internal emergency plan has been examined, within four months of the arrival of this review by the plan itself. The reviewer completes the examination of the missing information on the contingency plan, which is not sufficient, within one month of the arrival of the missing information.

(9) The operator shall provide the necessary information in the case that additional information is requested in writing by the Ministry of Environment and Urban Planning at the stage of examining the internal emergency plan.

(10) As a result of examining the content and sufficiency of the internal emergency plan, the Ministry of Environment and Urbanism shall; The result of the investigation shall be in accordance with the internal emergency plan format specified in the communiqué to be issued pursuant to the twelfth paragraph of this article, and according to the said communiq, the internal emergency plan with the full information required in the internal emergency plan is sufficient. This shall be notified to the operator and shall be deemed to be sufficient for the internal emergency plan; To the Ministry of Labor and Social Security, to the Provincial Disaster and Emergency Directorate, to the Organized Industrial Zone Directorate in the Organization Organized Industrial Zone, to the Industrial Zone Directorate in case the organization is located in the Industrial Zone. If the result of the investigation is not in accordance with the internal emergency plan format specified in the notification to be issued pursuant to the twelfth item of this Article and if the information requested in the contingency plan is not complete according to the said notification, the format incompatibility and the operator shall be granted a maximum of two times, including sixty working days. Within sixty working days of each business day, the operator is obliged to remedy the format inconvenience and the missing information in the internal emergency plan, to deliver the whole of the final emergency plan including the missing or incomplete information to the Ministry of Environment and Urban Planning. These sixty business days shall commence on the day following the notification date of the declaration made by the Ministry of Environment and Urbanization to the enterprise. At the end of the period given to the operator; As a result of the examination of the internal emergency plan, the internal emergency plan is sufficient if it is determined that the operator has addressed format incompatibility and lack of information. This situation is informed to the operator and the sufficient internal contingency plan is sent to the Ministry of Labor and Social Security, the Provincial Disaster and Emergency Directorate, the Organized Industrial Zone, the Organized Industrial Zone Directorate, and the Enterprise Zone, the Industrial Zone Operation Directorate. Even though the Ministry of Environment and Urbanism has given a maximum of two times, the provisions of the Environmental Law dated 09/08/1983 and numbered 2872 shall apply in case the format inconvenience in the contingency plan is not remedied, missing information is not sent or information is missing.

(11) In case the operator does not send the internal emergency plan belonging to the organization or if there is no internal emergency plan, provisions of Environmental Law No. 2872 apply.

(12) The Ministry of Environment and Urbanization issues a communiq with the opinion of Prime Ministry Disaster and Emergency Management Presidency regarding emergency plans.

Article 14: (1) Regarding the higher level institutions within the scope of this Regulation, the Provincial Disaster and Emergency Directorates shall provide an external emergency, taking into account the notification specified in the twelfth paragraph of Article 13, provided that it is not less than the information specified in Annex-4, prepare or prepare a situation plan.

(2) The Provincial Disaster and Emergency Directorates shall prepare an external emergency plan or plans within 6 months.

(3) The operator shall provide any additional information requested by the Provincial Disaster and Emergency Directorate for the preparation of the external contingency plan within the requested period.

(4) The Provincial Disaster and Emergency Directorate is responsible for the preparation of the external

emergency plan; to exchange views with the operators. If necessary, information is obtained from the units carrying out the emergency service, from the Organized Industrial Zone Directorates, the Industrial Zone Management Directorates, the Provincial Disaster and Emergency Directorates of the neighboring provinces and the institutions and organizations which are covered by the external emergency plan.

(5) The external emergency plan shall be made accessible to the public by the Provincial Disaster and Emergency Directorate for at least 30 days in order to be able to provide information and opinions of the draft school.

(6) The Provincial Disaster and Emergency Directorate shall finalize the external emergency plan taking into consideration the views taken in accordance with the fourth and fifth paragraphs of this article and send one copy of this plan to the Prime Ministry Disaster and Emergency Management Authority and the Ministry of Environment and Urbanism.

Article 15: (1) The operator reviews the internal emergency plan at intervals not exceeding three years, revises it when necessary, updates it, applies the plan, and conducts the necessary work to ensure that the units performing the emergency service services participate adequately.

(2) The Provincial Disaster and Emergency Directorate, in intervals not exceeding three years, audits the external emergency plan and updates it if necessary, and cooperates with the units which execute the plan, the operators and emergency services.

Article 16: The operator who prepares the internal emergency plan in accordance with this Regulation applies this plan without delay when it comes to an uncontrolled event that could be expected to lead to a major accident or a major accident. In such a case, the Provincial Disaster and Emergency Directorate shall apply the prepared external emergency plan without delay, provided that the internal emergency plan is inadequate or inadequate. is expressed [50]. (Regulation on the Prevention and Reduction of Major Industrial Accidents Published in the Official Gazette dated 30.12.2013 numbered 28867).

7. Danger Communication

Hazard communication is used for communication purposes at the time of danger when procedures are prepared in advance about how to make communication in case of emergency using different visuals and signs (pictograms) for informing, warning, reminding, giving instructions about hazards and possible risks while preparing emergency plans in occupational health and safety [51,52].

Figure 4. The hazard communication signs [53].

Figure 4 shows some of the hazard communication signs. Communication is vital for prompt reporting of emergency situations, dangerous notification of personnel, immediate referral of emergency response teams and coordination between teams, informing employees and their families about the event, and providing information to supply and demand units [54]. Communication methods can be expressed as warning signs, messenger, telephone, radio, satellite systems, dial-up modem network, hand signals and communication systems [55, 56].

8. Related Legislation

Regarding the Regulations Emergency Plans for Emergency Situations in Establishments published in the Official Gazette dated 18.06.2013 and numbered 28681 as related legislation [57]. These;

Article 1- The purpose of this Regulation shall be the procedures and principles concerning the preparation of emergency plans in the workplaces, the work to be done in prevention, protection, evacuation, fighting against fire, first aid and similar matters and the management of these situations in a safe manner and determination of the employees to be assigned to these matters to regulate.

Article 2- This Regulation covers the establishments covered by the Law on Occupational Health and Safety No: 6331 of 20/6/2012.

Article 3- This Regulation has been prepared based on the 11th, 12th and 30th articles of the Occupational Health and Safety Law.

Article 4-In this Regulation; Emergency: emergency, such as fire, explosion, spread from dangerous chemical substances, natural disaster, struggle, first aid or evacuation, which may occur in all or part of the workplace. Emergency plan: The plan, including the work to be done in emergency situations that may occur in the workplace. Safe place: The place where the employees will not be affected by the negative consequences of the emergency or at the shelter.

Article 5- The obligations of the employer regarding the emergency situations are stated below: Identifies possible emergency situations by preliminarily evaluating

the emergency situations that will affect the working environment, the materials used, the work equipment and environmental conditions, and affect the working environment. Take measures to prevent and limit the adverse effects of emergency situations. Make necessary measurements and evaluations to avoid adverse effects of emergencies. Prepare emergency plans and provide exercises. Taking into account the size of the workplace and the specific hazards it carries, the nature of the work done, the number of employees and other persons in the workplace in order to combat emergencies; It has a sufficient number of trained and qualified personnel in the fields of prevention, protection, evacuation, fire fighting, first aid and similar matters, and ensures that they are always available. Make necessary arrangements to provide contact with out-of-work organizations, especially in the areas of first aid, emergency medical intervention, rescue and fire fighting. Arranges necessary arrangements for emergency dismantling of energy sources and dangerous systems don't create adverse conditions and not to affect the protective systems. Informs the employer established the temporary business relationship and other persons in the workplace such as customers [57].

9. Conclusion

Occupational safety and health risks should be seen in relation to internal and external factors. The working environment may include one or a combination of cold, wind, ice, wildlife encounters, extended periods of darkness and light, noise, dust, biological hazards, etc [58-60]. These conditions, if not mitigated or controlled, can potentially cause or exacerbate illnesses and injuries such as carbon monoxide poisoning, frostbite, frostnip, hypothermia and seasonal affective disorder. The different factors involved may compound each other, making health issues more urgent to treat and safety issues more difficult to resolve. Working patterns may adversely affect workers' work–life balance. Excessive working hours and inadequate rest times may affect the health and well-being of workers. Strategies and tripartite commitments on prevention are essential in occupational safety and health. Policies should prioritize the most urgent challenges, consider the safety and health of workers, and recognize their rights to know the risks and to participate in mitigating the risks. The workers should have the right to refuse or stop unsafe work if there is a possibility of accident or injury. Governments and employers' and workers' organizations have shared responsibilities in the design and implementation of policies, actions and tools. Industry-wide programmes, such as "safety passport" schemes, may facilitate the prevention of accidents and illness and the promotion of workers' health and well-being, particularly among contractors and subcontractors. Care must be taken that the safety passport is not used as a substitute for job-specific education, training and skills. Other standardized systems, like personal protective equipment specifications and accredited training systems, may also be helpful. Elected worker health and safety representatives and/or members of Joint Health and Safety Committees should receive additional training specific to their responsibilities. All parties, such as authorities, and employers' and workers' representatives, should be involved in developing specific training tools. Multiple skills sets need to be taken into consideration in their design, development and implementation. Appropriate safety, apprenticeship and recruitment programmes, as well as emergency communication and response preparedness, can help workers and enterprises manage risks that affect work in working environment.

As a result, the employer is obliged to prepare the emergency action plans in the workplace in order to avoid negative consequences in the above-mentioned emergencies. In the study, occupational health and safety measures and interventions to be taken against emergencies are described. Emergency action plans will identify emergency situations, such as risk assessments, the likelihood of fires, the probability of explosion from hazardous chemical substances, situations requiring first aid and evacuation, natural disasters and sabotage probabilities, starting from the installation phase for all workplaces. It is prepared by following the revision stages of the contingency plans by taking the many preventive and limiting measures to prevent their adverse effects, determining the teams to be assigned, setting up the intervention to be urgently urgent and establishing the evacuation methods of employees, documentation, exercises. There is no enough study in the literature about preparing emergency plans. In this study, it is proposed how to prepare the contingency plans by filling this gap in the literature.

10. Discussions

There are many emergency situations in public institutions such as sabotage, fire, explosion, food poisoning and natural disasters. In this study, the stages of preparation of the emergency plan have been dealt with in order to prepare the institutions for emergencies. Emergency plan studies of leading institutions and organizations that conduct research and development in the field of occupational health and safety and support these studies with documents and guides are available. Compared to the Emergency Plan headings to be prepared in accordance with the provisions of the Occupational Safety and Health Administration (OSHA) and Emergency Situations in the Workplace, the content headings of Occupational Safety and Health Administration appear to be more generic. According to Occupational Health and Safety legislation, the contingency plan items are specified in more detail and subordinate items. Unlike Occupational Safety and Health Administration, an emergency plan prepared under the Regulation on Emergency Situations in the Workplace states that "the identification of preventive and restrictive measures", the detailed information of the evacuation plan (places where emergency equipment is located, places where first aid equipment is located, escape routes, emergency evacuation plans, emergency contact numbers, emergency contact numbers). Preparing an emergency plan as well as occupational health and safety work is a product of a continuing process. Some of the hurdles in the process of preparing an emergency plan for public institutions in particular are:

• Difficulty in carrying out a systematic work due to the fact that it is not directly related to occupational health and safety,

• Public institutions performing office-based work are less concerned with emergencies and emergency equipment than industrial enterprises,

• Difficulty in finding a safe location because most public institutions operate in more restricted areas than large enterprises in the industry,

• Problems arise due to the bureaucratic problems in public institutions related to the emergency plan.

The General Directorate of Occupational Health and Safety should publish the Emergency Plan Preparation Guide for Workplaces. Emergency preparedness and emergency plan preparation trainings should be given in public institutions. For each emergency, brochures should be prepared which include identification, preventive limitative measures and intervention methods. In case of emergency such as fire, explosion, earthquake, banners should be prepared in such a way that important information will appeal to the subconscious. Public spots for emergencies of each sector should be drawn up by cooperating with the unions in different sectors and must be transferred to employers and employees through unions.

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Review Article

Examination of the Obesogenic Effects of Bisphenol-A

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ABSTRACT

The prevalence of obesity among people has increased dramatically in recent years in all the world. It is not enough to explain this increasing trend only with people's lifestyle, eating habits and cultural differences. Some chemicals, which are taken into the human body, especially through the food chain and are considered to be endocrine disruptors, affect the frequency of obesity. Endocrine disrupting chemicals (EDCs) are compounds that cause hormone disruption and elimination of the functions of these hormones. Bisphenol-A (BPA) is one of the most intensive chemicals in human life and is generally called 2,2-bis (4-hydroxyphenyl) propane. 70% of the BPA in the world is used in polycarbonate plastics and 30% in epoxy resins. Due to the widespread usage of it, BPA reaches solid and liquid wastes in terrestrial and aquatic ecosystems in large quantities. Considering the high production capacity of BPA and its different application areas, it is claimed that significant amount of BPA enters the environment. Studies show that the rate of being exposed to BPA has an increasing tendency. In the literature, the rate of availability in drinking water and the data on the reproductive system were only included in the researches related to BPA. Therefore, this study aimed to observe the obesogenic role of BPA in the development of obesity, which is the current health problem of the world. BPA is an endocrine disrupting chemical known to have in vitro effects on glucose metabolism and adipose tissue. In a limited number of clinical and epidemiological studies, BPA has been shown to be associated with diabetes and obesity. For this purpose, the current literature related to this issue has been reviewed and the effects of BPA on obesity have been compiled both in the world and in our country.

1. Introduction

Nowadays, obesity is accepted as an important issue that is called as a widespread worldwide problem by the international standards and it is a persistent illness that needs treatment. Obesity prevalence has increased markedly over the past few decades. The worldwide prevalence of obesity is increasing at an alarming rate. Cumulative evidence offers that ecological components, especially hormonal disorder compounds, may also have a role in the rise of obesity (see Figure 1) [1, 2]. Obesity is a problem for all ages, and the number of children and youths who are overweight has risen in parallel with the rates reported in adults [3]. With important social and mental responses, obesity is a sophisticated illness affecting nearly all ages, genders, and ethnic groups. Moreover, obesity and excess weight are major contributors to the international load of chronic illness and are link to type 2 diabetes, heart disease, gout, liver disease, kidney disease, and some forms of cancer [3]. Childhood obesity has become one of the most important health issues of the last 10 years. Obesity can affect a kid's body health through cardiovascular, hormone, psychosocial situation, irregular eating habits, and depression [1, 2]. Obesity can also effect success at school. In addition to sanitary effects, childhood obesity has also economical conclusions [3, 4] (Figure 2). In OECD countries, according to Body Mass Index (BMI) values, the obesity rate ranged from 15% (Norway) to 45% (Chile). In addition, the obesity level in different age groups is identified as 26% on average in males and 24% in females. The prevalence of overweight women is higher than men in some countries (Figure 3).

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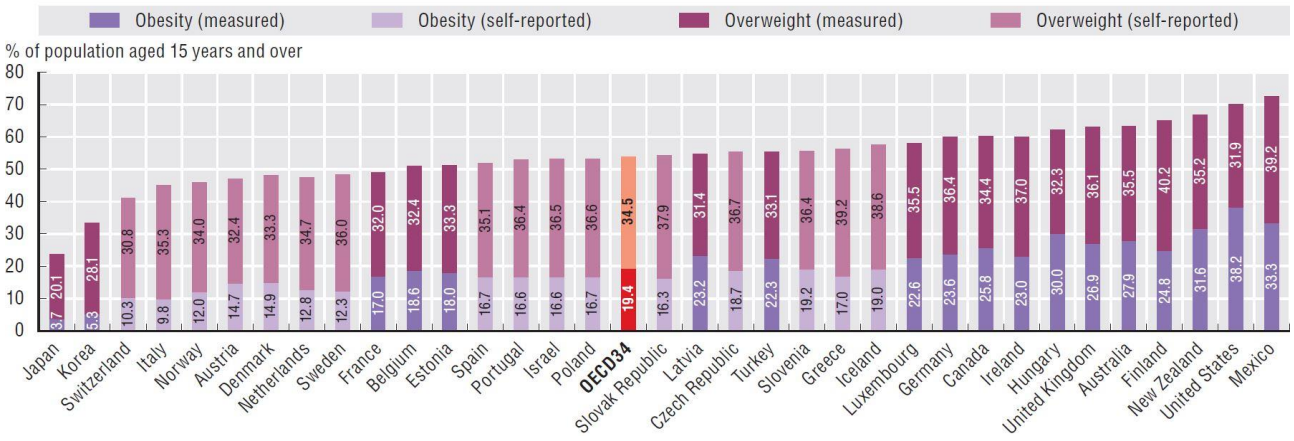

Figure 2: Obesity rates for OECD countries in 2015 or nearest year [2, 105].

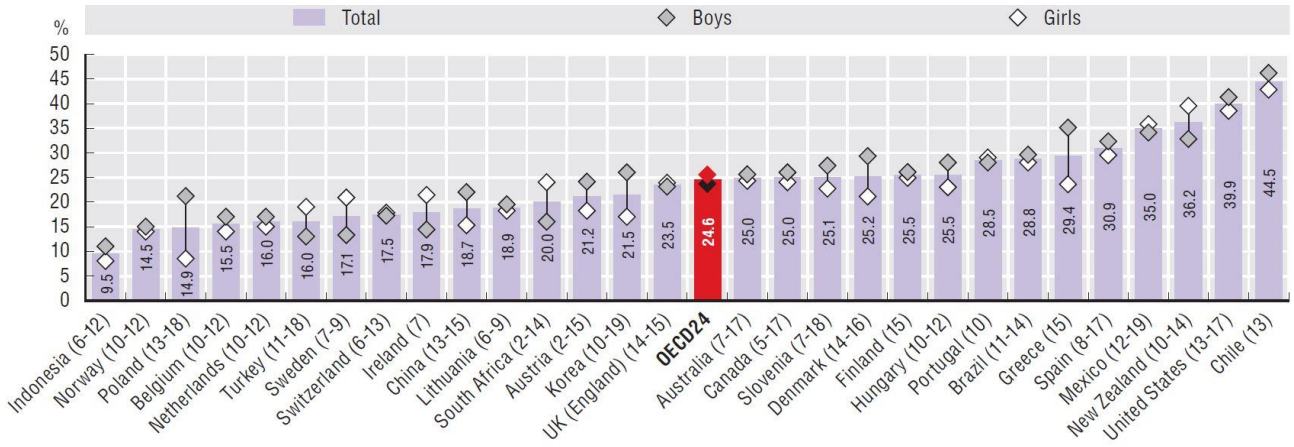

Figure 3: In some countries between the ages of 6 and 19, the distribution of obesity among children in the last 5 years [2, 105].

Nowadays, a lot of contaminants called as endocrine-disrupting (diethylstilbestrol, persistent organic pollutants, Bisphenol A, phthalates, polybrominated biphenyls, 4-Nonylphenol, parabens, phytoestrogens) is indicated to break the activities of hormones. Also, such chemicals are termed as “obesogens”. These chemicals themselves and their by-products are heavily involved in nature as a result of human activities. Throughout their daily lives, human beings are now exposed to this obesogens in external and internal habitats through their usage of pesticides, industrial and domestic products, plastics, cleaners, cosmetics. The input of them to the living system may be through oral, respiration or dermal suction [4-6]. From farm to fork, our food carries thousands of obesogens that we consume. Obesogens cause weight increase by changing fat homeostasis to promote the fat collection, and this may occur through the complex systems summarized in Figure 4 [2]. With their different hormone-like activities, endocrine-disrupting contaminants, which can be classified into persistent and non-persistent groups depending on their biodegradation and bioaccumulation properties, have diverse effect on the endocrine systems. [7].

BPA (2,2’-bis-4-hydroxyphenyl-propane) is an endocrine-disrupting chemical produced in large quantities worldwide [8]. BPA, which was first produced in the 1940s as an artificial estrogen, is used for its diagonal-structure features in the production of carboy materials, which are immanent in user products such as plastic materials, platings on food, thermic paper [9]. 2,2’-bis-4-hydroxyphenyl-propane is one of the World’s maximum generation capacity obesogens [10-14]. At the present time in the science world, the harmful effect of a phenolic type of ecological toxic substances, known as BPA, has attracted the major attention [15].

Table 1. BPA concentrations in the major sources [17].

Affected Sources	BPA Concentration	Units
Aquatic media	8000-21000	ng/L
Air	0.002-0.208	ng/L
Dust	800-10000	ng/g
Thermal paper	54000-79000	ng/cm^2
Fish	5-109	ng/g
Foods	9-76	ng/g
Cosmetics	21-43	ng/g
Cans	2-82	ng/g
Plastics	0.2-26	ng/g
Dental materials	13000-30000	ng

Suitable sources of possible exposure to BPA in habitats are shown in Table 1 [16, 17]. Since BPA is classified as an obesogen related to some disease in cell and animal models, apprehension has increased for community health [10]. Several epidemiological studies have also found results on the associations of BPA levels with some diseases such as type 2 diabetes, heart illness, obesity and sexual disorders [13]. In this study, the aim of the literature search was to find all studies examining the relationship between BPA exposure and human health or physiological changes in humans.

2. Material and Methods

With no time or language limitations, all academic fields focusing on the environmental obesogens were detected by using MEDLINE, PubMed, Google Scholar, ISIWeb of Science, Springer, Taylor-Francis, Elsevier, and Scopus. The scientific studies were monitored during May, June, July and August 2017. Searching process in all the databases was conducted through using the different keywords (endocrine disruptors and chemicals, obesogen, BPA, BPA and obesity, obesity and overweight, excess weight, body mass index, weight gain, childhood obesity, etc.).

3. Literature Survey and Discussion

2,2'-bis-4-hydroxyphenyl-propane is an obesogen of synthetic polymer used in all packing and in epoxy resins used as coverings in nutrient boxes. With the biological monitoring system applied today, BPA monitoring can be performed in urine and blood samples of 93% of the people. [18]. Scholars have determined BPA in the blood of mature women, in navel cord liquid and in placenta [19, 20]. In the experimental studies with laboratory animals, it was found that BPA affected the reproductive system negatively [21]. In all studies conducted to identify BPA, it was observed that especially in the childhood period, the hormone system collapsed and cancer types became prevalent [22-25]. In both male and female, higher BPA levels in urine were associated with different diseases (diabetes, obesity etc.) [26-30]. In some studies, on all living beings, there was an expanding proof related to BPA's obesogenic impacts. It was found that perinatal and postnatal exposure to BPA in aquatic solution was related to increase in heaviness and whole cholesterol in lab mouse [31-41]. Some literature review was conducted to find all studies examining the association between BPA exposure and childhood obesity [42-47]. In the academic field, some research has tried to explain the technics of mutual effect of BPA and hormones. Especially, in-vitro and in-vivo studies have supported the theory of exposure to BPA [49-51]. In recent years, it has been determined that BPA content materials used intensively in childhood increase obesity and diabetes. [52-54]. Table 2 presents the major medical studies that examined the relationships between BPA and early-age obesity. Certain scientific research recorded the link of the exposure to some obesogens with obesity. BPA is one of the obesogens described by the experimental studies [55-61]. Previous studies have supported the link between obesity and low dose exposure to endocrine disrupting chemical such as BPA, which are commonly found in plastics, dental equipment, food, beverage cans [62, 63]. Summarizing the effects of obesogens, because of their lipophilic structure, they increase the rate of fat retention in living beings [64].

There is no study examining the obesogenic effects of BPA in our country. Recently, the prevalence of obesity and childhood obesity has been examined in Turkey. Childhood obesity is a major issue in Turkey (Table 3). In a study conducted in Istanbul on children between 1-11 years old, it was indicated that 36.1% of the children were fat or obese [65]. It has been noticed in the other studies that some of the parameters of obesity-causes in the childhood period are heritage, gender, ethnicity, eating habits, amount of nourishment between 0-1 years, and insufficient physical activities [66, 67]. The aim of the study in the Çorum was to define the results in terms of being overweight or obese for children from 3 to 6 years old and to guide the children and their parents in making healthy nutrition selections by informing them. Findings of the research indicated that 26% of the test subjects who joined in the study were fat or obese [66]. In national and international studies, it has been notified that boys are more obese in comparison to girls [68]. Other studies conducted in these regions have shown a more obesity rate in men than in women. Obesity is more extensive among men in Turkey because we have a male dominated society and thus more attention is given to boys' nourishment [66, 69-73]. In another study, Şenyıldız et al. [74] examined the effects of BPA on gene evidences, histone changes and endocrine disrupting chronic toxicity in the population. The potential health impacts of BPA on urinary system, including the seminal mechanism, and pubertal improving was discussed by depending on some of the available literature [75-83]. Balcı et al. [79] investigated the mutual effect of phthalates and BPA with both adipogenesis and obesity by promotion in artificial environment, animal and human results. In the available research, Topçu et al. [78] intended to consider effects of the psychologic status in fat children.

The results, inclusive in this short compilation, support a hormone system connection between the exposure to EDCs and the increasing of obesity. The obesogenic effects of EDCs are not only caused by chemicals. At the same time, people's genetic structures, eating habits and lifestyle also affect obesity. In Turkey, use of BPA was banned in baby bottles, and other polycarbonate baby

products in July 2012 by a regulation which was included in the Turkish Food Codex-baby formulas [84-87]. However, there are still cheap baby bottles, toys, or baby care products containing BPA in the market. On the other hand, in worldwide and Turkey, there is a tendency to consume easily made, tinned, or packaged food instead of home-made nutrition among children and adults. As the number of working women rise, it is inevitable that nutrition of boys and girls will be fast-food or microwave-meal.

3. Conclusions

The studies in the literature show that exposure of everybody to obesogens will cause excess weight and obesity. The number of research related to obesogens and especially the effect of BPA on children, is increasing day by day. However, because of the higher sensitivity of child to peripheral compounds exposures and for specifying systems of the obesogenic impacts of BPA, extra studies are required to investigate the relationship between BPA response and childhood health results. Several countries have issued regulations to ban the usage of BPA in specific products, such as baby bottles. Similar applications should be proceed to modify BPA with different plastic materials and to decrease the influences of these components.

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Table 2. Abstract of investigations evaluative the relationship between BPA and different illness.

Disease Type	Study population (person)	Population type	BPA Amount (ng/ml)	References
Diabetes	3516	Adults (≥40 aged)	1.43-2.22	[44]
Obesity	1455	Adults (≥40 aged)	4.5-4.7	[48]
Diabetes/Obesity	296	Female	1.38	[49]
Type 2 diabetes	3423	Adults (≥40 aged)	0.8-2.1	[50, 51]
Obesity	76	Male	1.04	[52]
cardiovascular diseases	596	Male/Female	1.3-1.5	[53]
cardiovascular diseases	1619	Adults (≥30 aged)	1.2-1.4	[54]
Obesity	977	Adults (≥40 aged)	0.8-5.0	[55]
Obesity	2747	Teenagers (≥18 aged)	2.1	[56]
Obesity	890	Adults (≥70 aged)	2.1-3.9	[57]
Obesity/ Type 2 diabetes	3390	Adults (≥40 aged)	0.8	[58]
Obesity	223	Teenagers (≥18 aged)	2.85	[59]
Sex Hormones	282	Female	2.3	[60]
Obesity	3967	Teenagers (≥20 aged)	3.9-4.0	[37].
Obesity	85	Female	1.5-1.7	[61]
Obesity	82	Male/Female	1.3	[62]
Obesity	1521	Adults (≥40 aged)	0.6-2.6	[63]
Obesity	2200	Teenagers (6-18 aged)	15.-5.4	[64]

Table 3. Selected studies on overweight/obesity prevalence among children and adults in Turkey.

Previous Studies	Year	Regions	Age ranges	Obesity (%)	Overweight (%)
[88]	2001	İstanbul	3-18	4.3	17.6
[89]	2002-2003	Antalya	6-17	3.6	14.3
[90]	2004	Ankara	10-16	3.6	10.7
[91]	2004	Kayseri	6-17	1.6	10.6
[92]	2005	Aydın	6-16	3.7	12.2
[93]	2007	Elazığ	6-11	1.6	13.2
[94]	2008	Bursa	6-12	10	12.4
[95]	2008	Bolu	6-17	6.1	10.3
[96]	2009	İzmir	2-15	6.3	9.9
[97]	2009	Kocaeli	10-19	6.8	11.5
[98]	2009	Samsun	11-14	10.3	22.4
[99]	2009-2010	Kayseri	0-7	4.9	10
[100]	2010	Van	6-18	2.2	11.1
[101]	2010-2011	Ankara	11-18	7.7	11.1
[102]	2011	Mardin	6-15	10.6	15.8
[66]	2016	Çorum	3-6	12.1	14.3
[103]	2008	Tokat	≥18	29.5	30
[104]	2007-2009	İzmir	≥30	39.1	37.4

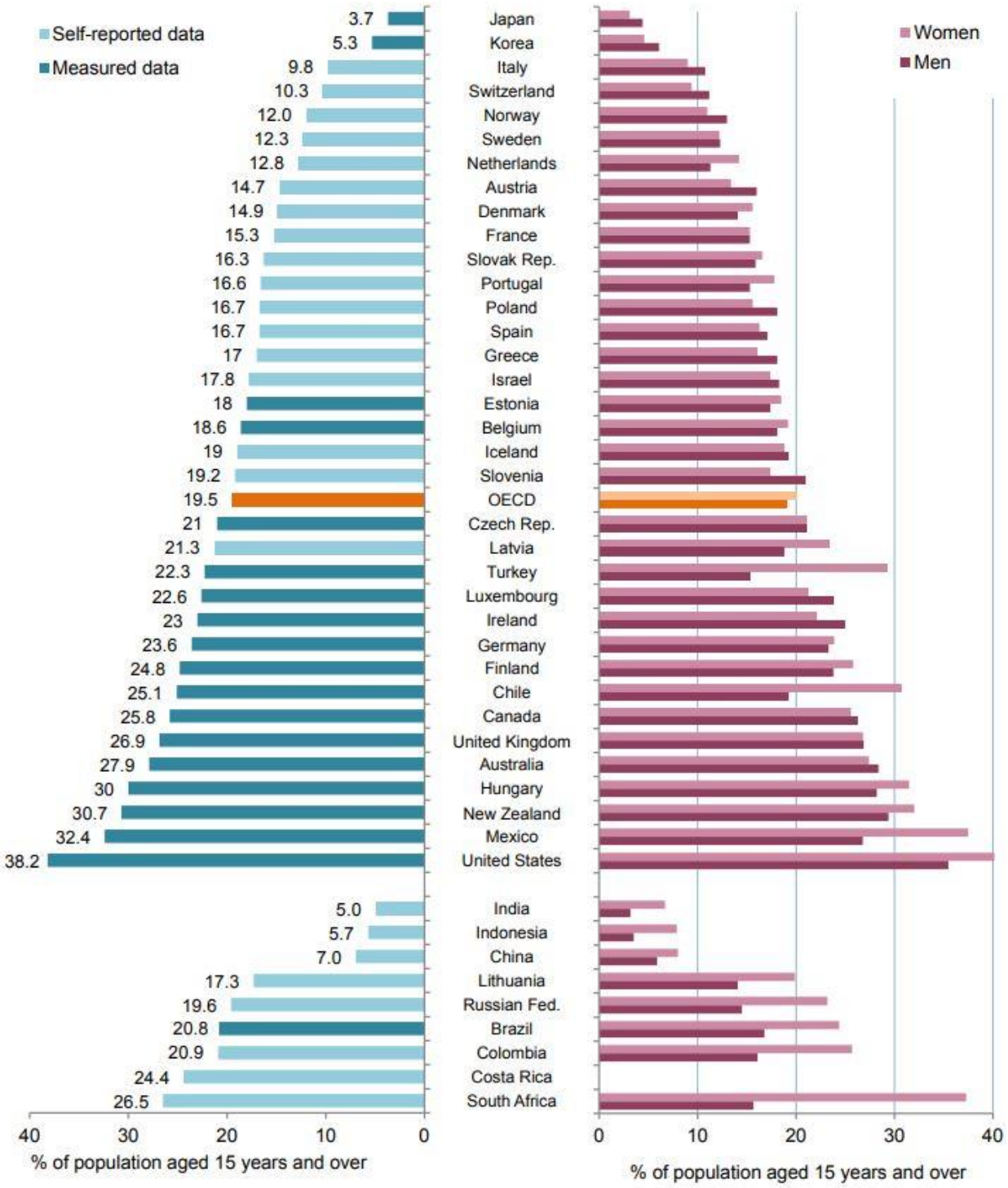

Figure 1: Obesity among adults, 2015 or nearest year, OECD Health Statistics 2017 [105].

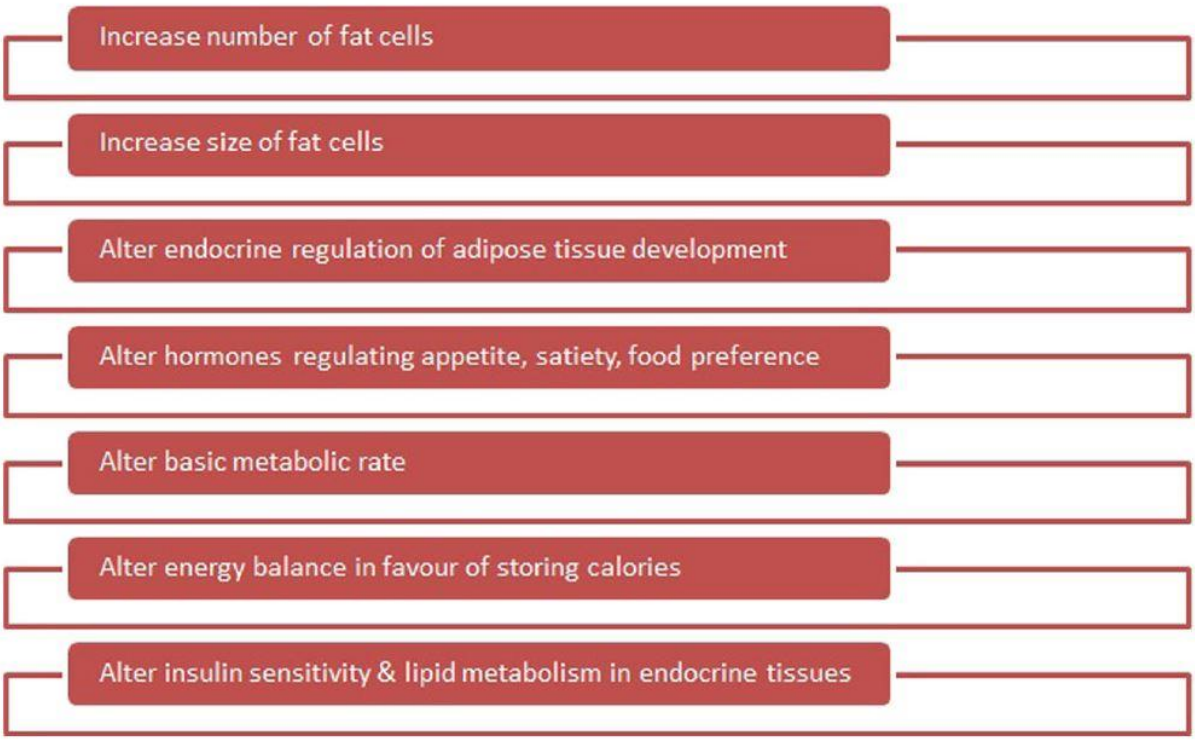

Figure 4: Summary of the mechanisms of obesogens [2].

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Review Article

Use of solar panels in greenhouse soil disinfection

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ABSTRACT

Restrictions on pesticides used in greenhouses around the world have led investigators and employees to take advantage of renewable energy sources in agriculture. In this study, solar panels (photovoltaic battery) and their us in soil disinfection in greenhouses have been discussed as a use of renewable energy sources in agriculture. Soil disinfection can be done by placing the resistance wires with low electricity consumption (25 W m^{-1}) and increasing the soil temperature to the required levels by using the electricity obtained from the solar panels. Thus, soil disinfection can be achieved by increasing the soil temperature. With high temperatures the duration of soil disinfection can be shortened considerably. Solarization application made with transparent plastic covering that is covered on greenhouse soil will also increase the success of disinfection. These practices are implemented in summer, when there is no production in the greenhouse and the weather is hot. The use of solar panels in the autumn, winter and spring months of production in the greenhouse will be for different purpose. The resulting electrical energy can also provide the energy of the ventilators used for forced ventilation of the greenhouse. It can also be used to meet the energy needs of some tools and equipment to be used in the lighting of the greenhouse.

1. Introduction

Major part of energy sources utilized worldwide are fossil energy sources such as natural gas and petroleum which lead to environmental issues. Utilization of ecofriendly renewable energy sources instead of fossil fuels, which introduce greenhouse gases and are running low in reserves and are leading to significant issues in the atmosphere, are becoming common place. Moreover, numerous studies on renewable energy resources are conducted in many counties and they are supported by the governments.

Sun is the world's leading, renewable and infinite source of energy. There are other sources of energy such as wind, sea waves, warm ocean currents, and biomass, however, they are possible solar energy. Sunlight consists of small energy packets called photons. Photons received from the sun every minute transmit energy in the amount which meets the world's annual energy requirement [2].

It is possible to generate heat and electric power directly from solar power [27], [3]. As seen in Chart 1, there is too much solar energy according to the renewable energy sources worldwide [14]. What makes solar energy valuable compared to other renewable energy sources is that it is ready-to-use worldwide.

Table 1. Worldwide renewable energy sources and their potentials [16]

Source of Energy	**Energy Potential (TW)**
Wind energy	2-4
Hydroelectric energy	0,5
Geothermal energy	12
Tide and ocean currents energy	2
Solar energy	120.000

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(TW=terawatt=$1x10^{12}$ watt)

European Commission for Energy has adopted a resolution to increase renewable energy sources utilized throughout the Europe. With this resolution, it is decided that the share of renewable energy sources utilized in European countries shall be increased up to %20 in overall utilized energy until 2020 [21].

EPDK (Energy Market Regulatory Authority) has promoted utilization of solar energy in 38 cities in Turkey. Konya is in the first place with 92 mW (megawatts) of investment. It is declared that 85% discount will be applied to lease servitude right of use permit fees for the first ten years of investments to be made to such cities [5].

1.1. Solar Energy Potential of Turkey

It is possible to consider Turkey to be fortunate in terms of solar energy compared to many countries. Sunshine duration varies based on seasons and regions. Our country is divided into three categories in west-east direction in terms of total solar radiation. While the radiation level is 1400-1500 kWh $m^{-2}year^{-1}$in Marmara and Black Sea regions, it is 1500-1600 kWh $m^{-2}year^{-1}$in Aegean, inner regions of Central Anatolia, and northern parts of Eastern Anatolia, and around 1600-1750 kWh $m^{-2}year^{-1}$in Mediterranean and Southeastern Anatolia [5].

Sunshine durations in our country vary seasonally. Daily sunshine duration is approximately 5 hours in winter, 7 hours in spring, and 11 hours in summer months [4].

It is determined that annual average sunshine duration of Turkey is 2640 hours (daily average is 7,2 hours), and total average radiant intensity is 1311 kWh m^{-2} $year^{-1}$ (total daily average is 3,6 kWh $m^{-2}day^{-1}$) [19]. Total average radiant intensity for Tekirdağ province in which this study is conducted is 1281,2 kWh $m^{-2}year^{-1}$, and very close to Turkey average (97,7%). Sonar panels are required to generate electric power directly from sunlight, and solar collectors are required to generate thermal energy from the sun.

1.2. Solar Panels

It is mentioned that solar panels can be used to generate electric power economically in rural areas where there is no electrical network [11]. Therefore, electricity usage in agricultural establishments, greenhouses, and livestock establishments in rural areas become widespread. They provide the electrical energy required by greenhouses to be used in lighting, ventilation, cooling, disinfection and electronic measuring instruments.

Solar panel is a photovoltaic equipment, which is composed of solar cells and converts sunlight directly to electric current. Solar cells are made from organic and inorganic bases. Generally inorganic based solar cells have a wider area of usage due to their 15-20% yield and higher efficiency [15].

Solar cells (photovoltaic cells) are semiconductors which convert the sunlight received by the surface directly to electrical energy. Materials such as silicon, gallium arsenide, cadmium wires are the optimum ones for building solar cells among many other semiconductors. Silicon is the most commonly used material. In order to use silicon as a solar cell, it must be doped with phosphorus and aluminum. Surfaces of the solar cells to be made of such material may be rectangular, square, and round. Surfaces typically have an area of 100 cm^2 and thickness of 0,2-0,4 mm. Solar cells are connected in parallel or series in order to boost the output power, and solar panels are produced by installing them on a surface [6].

Turkey is located in 36˚-42˚ north latitudes and 26˚-45˚ east meridians, and therefore solar panels must be installed with an angle of 60˚. Thus, solar panels in a solar energy system to be installed in our country must be directed to the sun with angle of 60˚ from the ground plane [7].

Efficiency rates of solar cells are determined according to 25˚C. System efficiency is decreased due to reasons such as high or low air temperatures, dusts, droppings (such as from birds) casting a shadow, and sunlight angle of incidence not being perpendicular [4].

This study lays emphasis on utilizing the sun as one of the renewable sources of energy in greenhouses in a different manner. Utilization of the electrical energy generated by solar panels in greenhouse soil disinfection is studied. Temperature generated by utilizing the generated electrical energy in resistance wires laid in the soil and solarization method are utilized together, and their effects on greenhouse soil disinfection are determined.

1.3. Solarization and Disinfection in Greenhouses

Greenhouses are not heated when the air temperature is low because such practice increases the operational costs extremely and causes the production to be expensive. Therefore, in general solar energy is used as the source of energy in greenhouse farming [28].

Greenhouse internal temperature and humidity are typically higher in greenhouses with monoculture practice. Low greenhouse soil air and high soil humidity due to irrigation causes rapid growth and spread of all kinds of diseases and pests in the greenhouse. The method which decreases soil diseases and impacts of pests on the soil to some extent for a healthy, efficient and quality production in greenhouses is disinfection.

Since the soil is porous and has a three-phase structure, the transfer of heat is quite slow. The heat transfer within the soil greatly depends on the structure of the soil as well as the water and air content of the soil [10]. Because of this, increasing the water content of the soil will help transfer of heat within the soil. It is desirable to increase the water content by watering the soil during solarization. When the water content of the soil come close to saturation the heat transfer of the soil increases [22;23;25].

Disease factors causing damages in cultivated plants and most of the nematodes are found in the soil. Physical and chemical control of these soil borne factors found in greenhouse soils is possible. Greenhouse soil is heated up to a specific temperature using various methods in physical disinfection. Certain extremely toxic chemicals (pesticides) are applied to the soil in chemical disinfection. This method is extremely harmful to both environment and human health, and negatively affects the natural balance. These chemicals may return to people in one form or another [19]. In addition, they have many undesirable effects such as resistance against disease, pests and weeds [14]. Today, chemical pesticides must be used in a conscious and controlled manner in order to ensure sustainable agricultural production and protect both human health and environmental. Chemical pesticide use must be restricted as much as possible by taking measures in this field [24], [12].

Use and production of MeBr, as one of the extremely toxic agricultural pesticides used in soil disinfection, is prohibited worldwide. Accordingly, studies are conducted on physical methods in which high temperatures are applied in soil pests control. It is found out that soil solarization applications are effective in removal of pests from greenhouse soil [17], [18]. In solarization method, soil surface is covered with a plastic cover, and sunlight ensures that the temperature of the soil under such cover increases.

Solarization is performed for heating the soil by using the solar energy in summer months when exterior temperature is high and the greenhouse is empty. This method has advantages such as being cost effective and having no adverse effects for the environment. However, minimum duration of application is long as 3-4 weeks [13].

Diseases and pests in the soil must be determined and soil temperature must be increased accordingly in application of physical disinfection methods. Temperature must be 71-77^{o}C for greenhouse soil disinfection. Increasing the temperature too much may cause the beneficial soil bacteria to lose their validity as well [26].

In consideration of the daily global intensity values of sunshine in Thrace Region, it is possible to generate electrical energy by using the solar panels system in the region. It is possible to make soil disinfection more effective by using such generated electrical energy in the resistance wires laid in the soil. Hazardous effects of the chemicals used in disinfection will be avoided and the cost will be eliminated by using this system. Generalizing the system especially in the cultivated plants with higher economic return will make it a more economic production method in addition to the consumer health and reduction of chemical inputs.

2. Material and Method

2.1. General Characteristics of Research Area

Research area is the Thrace Region located in northwest of Turkey and city center of Tekirdağ province. Thrace Region is located on European continent of Turkey between 26^{o}-29^{o} east longitudes and 40^{o}-42^{o} north latitudes. Moreover, Edirne, Kırklareli and Tekirdağ provinces are entirely, and European sides of Çanakkale and İstanbul provinces are located in this region. Location of the Research area is shown in Figure 1.

Figure 1. Research area location [8]

Tekirdağ province, in which the study is conducted, is located between 26^{o}41′-28^{o}10′ east longitudes and 40^{o}35′-41^{o}35′ north latitudes. Surface area is approximately 621788 ha. Land structure of Tekirdağ is slightly rugged, and the geological structure is very young. Current appearance of the province was formed in the quaternary period. Tekirdağ has sub-humid climate. Weather is windy in summer and winter months. Prevailing and continuous winds are northeaster and southwester [1].

Tekirdağ province is eligible for greenhouse cultivation in terms of climate, soil and water resources. There are good marketing opportunities for grown produce. It is very close to İstanbul, a major consumption center, and just 135 km's away [28].

2.2. Solar Panel System Design

A system to be installed using solar panels for greenhouse soil disinfection (Figure 2) may consist of

solar panels, battery set, battery charging regulator, inverter, auxiliary electronic circuits, and resistance wires for heating the soil [4].

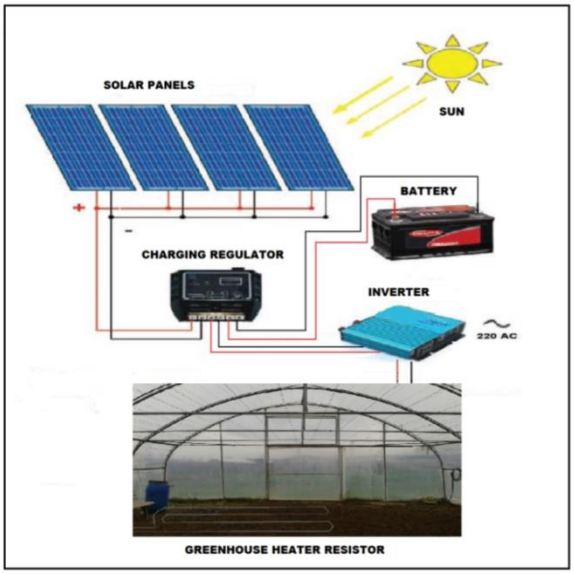

Figure 2. Components of greenhouse soil disinfection system with solar panels

Number of photovoltaic (solar) panels which covert sunlight to electrical energy are determined based on the amount of energy required. While panel efficiencies vary based on the type of panel, which are usually 15-20%. As previously mentioned, certain external factors decrease panel efficiency. Therefore, it is better to use panels with a capacity slightly higher than the calculated power requirement.

Battery set is added to the system for storing the electrical energy. Such battery set is used to provide energy and run the system when there is no solar energy.

Batter charging regulator regulates the current coming from the solar panel, and prevents the battery from overcharging or completely discharging. Thus, battery damage is avoided. Charging regulator disconnects the incoming current or the current drawn by the load based on the battery state.

Inverter is used in applications requiring alternating current in order to convert the direct current power generated by the panels to alternating current power. There are typically two types of inverters with and without full sinus output. Inverter with full sinus output capability must be used for systems with precision instruments [4].

Utilization of the energy obtained from the solar panel system in greenhouse soil disinfection is possible with converting such energy to thermal energy. Resistance wires laid in the soil must be used for this purpose. Such wires shall not generate temperatures higher than 85-90^{o}C. High temperatures cause not only the harmful soil bacteria but also the useful soil bacteria to lose their vitality. Rheostat or dimmer must be added to the system in order to adjust the temperature in case the resistance wires generate higher temperatures. These soil temperatures should be measured and recorded with various thermometers.

2.3. Solar Panel Utilization in Greenhouse Soil Disinfection

Utilization of electrical energy generated by solar panels in greenhouse soil disinfection is possible by converting such energy to thermal energy. Thermal energy derived from such procedure shall not exceed 80-90^{o}C. The reason is beneficial bacteria in the soil are capable of maintaining their vitalities up to such temperatures.

Resistance wires or heating bands are used in the system in order to generate thermal energy from electrical energy [9]. Such resistance wires must be soil- and water-resistant in order to be utilized in the greenhouses. Energy consumption of resistance wires produced for such purpose is 25 W m^{-1}or the heating bands have an energy consumption of 17-18 W m^{-1}. Occasionally it may be necessary to utilize the resistance wires at temperatures below 80-90^{o}C. Soil heating may be required to boost root activities of the plants cultivated in the greenhouses especially in colder seasons and promote their rapid growth. Increased water and nutrient intake through plant roots ensures increased efficiency as well [20]. Rheostat or dimmer must be added to the system in order to adjust the electrical current intensity and lower the temperature in such cases.

Soil disinfection is more effective and completed in a shorter time with solar panel system in greenhouses where solarization is applied. The reason is that it is possible to achieve higher temperatures with such system. It is stated that greenhouse soil disinfection must be applied for minimum 4 weeks with solarization [19]. Temperature varies between 45-55^{o}C up to 10 cm soil depth with solarization [25]. Main target is to increase the soil temperature which decreases the efficiency of diseased factors, nematode and microorganisms in the soil. It is possible to increase the greenhouse soil temperature to approximately 80-90^{o}C using resistance wires with solar panels. This might ensure that soil disinfection is completed one week earlier.

3. Conclusions

Electrical energy generated by solar panel system may be utilized in greenhouses in various manners at various times.

Solar panels to be installed and the electrical energy generated may be utilized for heating and disinfection

of greenhouse soils with solarization applied in summer. For this purpose, resistance wires or heating bands may be inserted to greenhouse soils in 25-50cm intervals at 10-15cm depths.

Power of the system installed with solar panels is approximately 4 kWh. However, as previously mentioned, it shall be possible to continuously utilize approximately 3 kWh of such power. Resistance wires with 25 W m^{-1} energy consumption are capable of heating 120 m section with 3 kWh. It is possible to disinfect an area approximately 60-120 m^2 by laying such wires in the greenhouse soil in 25-50 cm intervals. It may be possible to disinfect a wider area by frequently relocating the resistance wires used in the greenhouse soil.

It is possible to disinfect the soil in a very short time with solarization.

It is possible to heat the plant's root area in the production seasons of fall, winter and spring. Dimmer must be added to the system for such purpose. Lower temperatures can be achieved by decreasing the amount of energy supplied to the resistance wires using the dimmer. It is possible to heat a wider area by increasing the length of resistance wire to be utilized. Thus, the amount of water and nutrient intake by the plant is increased by improved plant root activity, and plant efficiency is also increased.

It is possible to utilize the energy generated by the solar panel system for the ventilation required in the greenhouses during the production period. It is also possible to cool the greenhouses with fans and pads utilized with required ventilation.

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Review Article

Biosensors from the First Generation to Nano-biosensors

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ABSTRACT

All living creatures tend to sense the changes in their habitat and have to comply with them to survive. At first, the basics of the biosensor theory began with *in vitro* studies based on sensing ability of living beings. Then, scientists have started to use this ability in some devices. Lately, these devices have been smaller and smaller. They are in used for medical, chemical, food and some other sciences to make easier, cheaper, accurate and rapid detection of specific reactions, compounds, enzymes, cells according to their electrical, thermal or optical signals. Lastly, the 4th generation of biosensor technology, as lived now, has started with the developments of Micro, Nano or BioNano Electro-Mechanical Systems (MEMS/NEMS/BioNEMS), nanotechnology and biotechnology that are expected to have lots of features. Furthermore molecular recognition elements like aptamers which are synthetic oligonucleotide ligands against various target molecules ranging from small ions to large proteins, toxins and other analytes as receptors. The studies on using aptamers conjugated with nanomaterials to fabricate and design novel biosensors appear to continue due to various advantages such as frequency of usage, practical use and time-saving.

1. Introduction

All living creatures tend to sense the changes in their habitat and comply with them to survive. These creatures have the ability of sensing over the imagination of all scientists. The dogs' smelling ability, the eels' sensing ability of a little difference in tons of water, the butterflies' having a sense on their partners' secretion, the algae' sensing of toxins are some examples in nature [1].

The basics of the biosensor theory have commenced with *in vitro* studies based on mimicking of living creatures' sensing ability. Biosensor technology has come up with this idea and developed so fast. Later on, International Union of Pure and Applied Chemistry (IUPAC) have established a commission to classify and name the biosensors in 1996 and defined the biosensor as: "A device that uses specific biochemical reactions mediated by isolated enzymes, immune systems, tissues, organelles or whole cells to detect chemical compounds usually by electrical, thermal or optical signals" [2]

Furthermore, this definition has been improved due to the recent developments of bio-microchips in science and technology. Smaller, cheaper and more accurate devices than microelectronics could be produced as the basics of biosensor systems which have the sensing mechanisms such as to see, to hear, to smell, to taste and to touch [3].

By the developments of nanotechnology which provides to be able to study, to manipulate, to create and to utilize of materials in miniature scale, biosensors could be reduced to nano size [4]. Nano-biosensors are the revolution in sensor technologies due to enabling rapid analyzes of multiple samples at desired time and place [5, 6]. Showing high performance in selectivity, biocompatibility, non-toxicity, reversibility, rapid response and the sensitivity of determination by utilizing nanomaterials to introduce lots of brand new signal transduction technologies have been in used recently (Table 1). Morphologies of nanotubes, nanowires, nanofibers, nanorods have also been effective on transduction of analytes [7]. Along with all these, biological material usage like aptamers as alternative molecules to sensing materials give its benefits to this area [8].

There have also been portable instruments which are

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able to analyze multiple components at one time [9]. These technologies provide us to work in enormous application areas which involve medicine, food, agricultural, bioprocess and/or national defense due to the bio-molecular interactions, by combining the biological and physicochemical or mechanical features of transducers, which give much better and more accurate datum than traditional methods such as nucleic acid microarrays [10].

Table 1. The Properties of the Biosensors' Parts [11][53]

Analyte	**Bio-component**	**Transducer based on**
Hormones	Enzymes	Electrochemical
Enzymes	Antibody	Semiconductors
Coenzymes	Cell	Optics
Substrate	Tissue	Photometric
Activator	Receptors	Fluorometric
Inhibitor	Microorganisms	Fluorometric
Antibody-Antigen	Nucleic Acid	Piezoelectric
Nucleic Acid	Lipids	Quartz Crystal Microbalance (QCM)
Microorganisms	Organelles	Micro cantilever
Vitamin B_{12}	Aptamer	Aptasensors

2. The history of biosensors

The first biosensor was designed by Clark and Lyons (1962) [12] using an enzyme electrode. In this system, glucose is the target substance and its oxidation reaction was triggered by glucose oxidase.

The voltage between electrodes was enough for reduction of O_2 and electric current was measured by the rate of the concentration of O_2. The reduction of electric current was directly proportional to glucose concentration.

Another important innovation in developing biosensors is the potentiometric urea electrode designed [13]. These type electrodes were classified as the first generation biosensors.

As the second generation biosensors, auxiliary enzymes and/or co-reactants are co-immobilized with the analyte converting enzyme in order to improve the analytical quality and to simplify the performance [14] as shown in Figure 1.

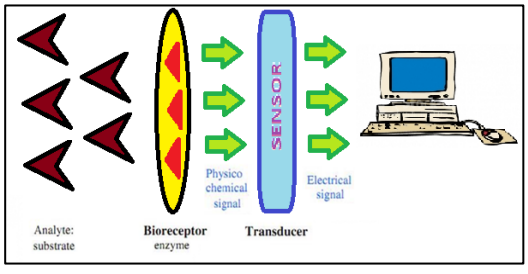

Figure 1. Schematic illustration of a biosensor

Typically, a transducer surface next to a biosensing material's attachments is modified by chemicals. ELISA (enzyme-linked immunosorbent assay) electrodes were included in this group.

In the third generation biosensors, biomolecules get involved to biosensing material such as SPR (Surface Plasmon Resonance) biosensors.

Lastly, for the 4th generation, with the developments in MEMS/NEMS/BioNEMS (Micro, Nano or BioNano Electro-Mechanical Systems), nanotechnology and biotechnology, are expected to have lots of features [15]. With the contributions of engineers and the scientists from different fields, biosensor production has many recent, creative and versatile opportunities to be developed. These biosensors are also used for the determination of biological and chemical effective substances in agricultural production, food analyzes and environmental monitoring in addition to mining, bioprocess, bio war and homeland security [8].

3. Applications of biosensors in agricultural and food industries

Biosensors have a transducer, a detector and a biological element (like enzyme, organelle or antibody) interacting with the analyte to give a meaningful response to read from the detector [11, 16]. They should have characteristics like the linearity of a calibration curve, the sensitivity of least amounts of concentration, the selectivity/specificity of getting true outcome and response time of at least %95 [17].

In the antibody-antigen interactions; an immunosensor is used for binding of an antibody to an antigen. There is a lock-key confirmation in this binding that results in physicochemical changes which constitute electrical signals. These interactions are irreversible and also depended on some conditions such as pH and temperature [18].

In the enzymatic interactions; analyte recognition is used for some mechanisms: a) enzyme converts the analyte into a product which can be detectable; b) enzyme interaction detection by the analyte; c) monitoring final properties of the enzyme. However, using this interaction limits the sensor's life based on the stability of the enzyme [19]. Enzyme-based biosensors and their use in industries were defined in the literature [20-23].

The use of nucleic acid as sensors' analyte is named as genosensors because of their recognition process, which is based on base pairing, cytosine: guanine and/or adenine: thymine in DNA. Based on known sequence, integral sequences can be synthesized, lined and immobilized. Then, the base pair is created and generate an optical signal [18].

The use of cells as sensors' analyte is based on their sensitivity to the environment, the responsibility of all kinds of stimulants and the reproducibility to be reusable. Cells are global bioreceptors to detect stress conditions, toxicity, organic derivates, effect of drugs, herbicides and the microbial corrosion [24, 25].

The use of organelles as sensors' analyte is based on their cellular functions through metabolic ways and enzymes'

effects. Mitochondria, for instance, give response to high calcium concentrations and high toxicity of detergent compounds [26].

Applications of biosensors especially in agricultural and food industries have focused on two folds: the first is to detect (and/or measure the amounts) of carbohydrates, alcohols, acids, amino acids, vitamins, amines, amides, phenol etc. in beverages; the second is to detect of microorganisms and components/toxins occurring by their affects [27].

Pathogen detection in foods and beverages has been one of the major challenges in biosensor technologies due to results in foodborne diseases in recent years. Ali et al [28] designed a biosensor to detect *E.coli* O157:H7 in food sample. While traditional methods took a few days to detection, they managed to detect *E.coli* O157:H7 in a few minutes by using AuNPs. Xiang et al [29] developed an electrochemical immunosensor to detect *Salmonella* based on gold nanoparticles (GNPs) dispersion in chitosan hydrogel and modified glassy carbon electrode (GCE). The demonstrated immunosensor was revealed as having good selectivity and reproducibility properties with a low sensitivity of 5 CFU/mL.

Biosensors specific to agricultural and food industries due to their analytes were given in Table 2.

Table 2. Some specific biosensors for various analytes in agricultural and food industries [16, 30, 31]

Biosensors	Analytes
Enzyme sensors	organic and inorganic substances (drugs, foods, vitamins, antibiotics)
Enzyme sensors	ingredients such as carbohydrates, alcohols and/or acids in quality control processes in the fermented food industry especially in wine, beer and yogurt production
Enzyme sensors (cholinesterase)	organophosphates and carbamates in pesticides
Microbial sensors	organic and inorganic substances (drugs, foods, vitamins, antibiotics) + dissolved oxygen needed by organisms
Microbial sensors	ammonia and methane
DNA sensors	viruses, pathogens, microorganisms
Immunosensor	viruses, pathogens, microorganisms and xenobiotics
Immunosensor	small amounts of molecules and pathogens which present in different kind of meat products
Aptasensors	various target molecules ranging from small ions to large proteins

4. Nano-biosensors in industry

These sensors work in the size of a few nanometers that they can detect the presence of nanomaterials or molecules in that size and even smaller. The application of nano-scale biosensors can differ from the transducer, the perception ligand, the label and the running instruments. Due to working advantages in miniaturization, nano-scale biosensors may be able to increase the sensitivity of the devices [4].

The nanomaterial should be selected for nanofabrication of the nano-sensor. In the process of nanofabricating, four methods are mostly in used: photolithography, thin film etching/growth, surface etching and chemical bonding. These kinds of patterning methods are needed for fabrication of the nano-structures easily and efficiently. Due to lithography (electron beam, X-ray and extreme UV) techniques, nano-scale electrode production could be managed and resulted in high accuracy of biosensing with a greater surface area to be accomplished in high precision [32, 33].

Variety of nanomaterials, such as metallic nanoparticles (i.e. GNPs which give different color in different nano size), carbon nanotubes (CNTs), magnetic nanoparticles (NPs) and quantum dots, which are nanoscale semiconductor devices, are used to design novel biosensors because of their high sensitivity and specificity of detection on materials' physical, chemical, physicochemical, mechanical, optics and magnetic features [34]. In producing of glucose biosensors, the enzyme of glucose oxidase is used. Furthermore, with a use of platinum nanoparticles over the sheets of carbon nanotubes helped to increase of immobilization of glucose oxidase to determine the analyte [35].

The glucose sensors have been widely utilized in medicine. GNPs, CNTs, magnetic NPs, platinum nanoparticles (Pt-NPs) and Quantum dots show excellent contribution in glucose sensors [36, 37]. Pt-NPs especially can be electrodeposited on multi-wall nanotubes (MWNTs) matrix in a simple and strong way. The immobilization of the enzyme (glucose oxidase) on the surface of Pt-MWNTs' electrode could be applied by chitosan-SiO_2 gel matrix. Thus, glucose levels of blood samples could be measured with high sensitivity [38].

Some organophosphorus pesticides (which are about 10^{-10} M concentration) could be monitored by liposome-based nano-biosensors at low amounts. Acetylcholine-esterase enzyme is used as fluorescent biosensor in this process [39]. In *E. coli* detection by flow injection analysis, a method was developed by using bismuth nanofilm modified GCE [34]. A biochip sensor system was designed with titanium pads and 150 nanometers Ti-well on a LiNbO3 substrate. If the bacteria were uninfected, a small value of voltage was carried out in the nanowell [40].

Another important phenomenon in biosensor technology is surface plasmon resonance (SPR). Its effects are based on the refractive index and the flow of light through a medium. Nanoparticles are also in used to maximize the ultimate scale optical response of the sensing materials with an incident light. Due to this light's effect, particles get excited from the surface as ionic species and resulted in fluids of their charged states. In this way, nanoparticles get photonic properties and they can be used as fluorophores

[41].

Along with all these, on the one hand, NEMS and MEMS technologies which are the combinations of biological materials and electromechanical systems, provide us to use of complex electrical, mechanical, fluidic, thermal, optical and magnetic properties of the materials at nano-scale.

MEMS and NEMS technologies have been combined with biological systems and molecules to have the best modeling of biochemical interactions to have good biosensing ability. MEMS and NEMS as biological sensing mechanisms are designed to measure of cellular structure surfaces using cantilevers as electrodes. The principle of the sensing is based on the thermal conductivity between the cantilever and the substrate changes according to the spacing between them [15].

On the other hand, molecular recognition elements like aptamers, which are single-stranded oligonucleotide sequences that are randomly chosen from sequencing pools as biosensing materials, are used in biosensors. In terms of the development of biosensors, aptamers are recognized as alternative molecular materials to antibody or other biomimetic sensing materials [8, 31]. Aptamers have the ability to bind the non-nucleic acid targets such as small molecules and proteins [42].

Aptamer probes are combined with electrochemical, optic, piezoelectric and magnetic transducers. Aptamers are able to be barcoded by radiation to detection of proteins qualitatively and quantitatively at the same time in a complex biologic matrix [43]. Li et al. [44] developed an electrochemical aptasensor to detect the adenosine simply and conveniently by measuring of impedance spectroscopy. Moreover compared to conventional sensing systems, this aptasensor system was mentioned as not only provided high sensitivity of detection, it also provided easily reusable sensing equipment. Besides reusability brought the cost-effectiveness together.

Medley et al. [45] revealed that previous methods were time-consuming, expensive and need complicated instrumentation and developed a new aptamer-based nanosensor. They thought that the selectivity and affinity of aptamers can be modified with nanomaterials to provide high sensitivity and accurate detection. The researchers developed a colorimetric test for the detection of diseased cells by using aptamer-conjugated GNPs (ACGNPs) to benefit of the selectivity and the affinity of aptamers and the spectroscopic advantages of GNPs. While previous methods needed much time, complex instruments and higher cost to develop, using ACGNPs required simple instrumentation and much lower cost.

Wang et al. [46] demostrated an aptamer-based silver (Ag) nanosensor to detect multiple proteins (Thrombin and Immunoglobulin E). According to the study, after target proteins and aptamer were introduced, aptamer-protein complexes have formed like key-locked or antigen-antibody models. Then by the removal of the aptamer part, fluorescent signals of the complex decreased. The researchers stated that this nanosensor provides high sensitivity, rapidity, high throughput, and miniaturization advantages. Moreover, revealing a comparison with the conventional systems, their sensor provided the detection of lower amounts due to being smaller and the process was very simple and low-cost.

Datta et al. [47] designed a sensor complex consisted of deoxyribonucleic acid (DNA) aptamer, GNPs and semiconductor quantum dot (QD), attached to a graphene oxide (GO) particle for detection of potassium at a very low concentration with high sensitivity in the field of medical detection applications.

Aptamers or single-stranded DNA-CNTs' (ssDNA-CNTs') probes could also be used for *in situ* sensing of the DNA hybridization events and detection of specific kinds of DNA oligonucleotides as optical nano-biosensors [48]. For the detection of deep DNA damages, a nano-bio-composite layer of MWNTs in chitosan was engineered [49]. Then, GNPs with alkane ethiol-capped DNA chimeras in a tail to tail hybridization mode of this DNA-CNTs show notable distinction between the integral part and base mismatch and fulfill perfectly [50]. In another example, a nano-SiO_2/*p*-aminothiophenol film which was self-assembled and electrodeposited was carried out to detect of *p*-aminothiophenol gene sequences by a label free electrochemical impedance spectroscopy (EIS) method [51].

Wang et al. [52] fabricated a single gold nanowire electrodes (Au-NWEs) by laser-assisted pulling/hydrofluoric acid (HF) etching technique, to develop an electrochemical aptamer-based nanosensors (E-AB nanosensor) to use for ATP determination even in a complex system like cerebrospinal fluid of rat brain. The researchers stated this E-AB nanosensor provides the unique properties of good stability, larger surface area and smaller overall dimensions in living bio-system.

In general, compared to the conventional methods, aptamer based nano-biosensors provide more benefits such as frequency of usage, practical use and time-saving, lower-cost, greater durability, reusability, simple instrumentation [44-46, 53-77].

As seen in the Table 3, same analytes can be detected by using different probes or transducers, providing different sensitivity and response time values. On the one hand, Apt-Au NPs as probe was used for adenosine detection based on colorimetric, SPR or electrochemical type transducers, which give responses between 20 seconds to 30 minutes with sensitivities from about 0.18nM to 2mM [53, 54, 78-80]. On the other hand, Apt-Au NPs or Apt-QD was used as probe for cocaine detection based on colorimetric or fluorometric transducer that give response between 20 seconds to 5 minutes with sensitivities of 2 μM to 2 mM [53, 55, 78, 81].

For Hg^{2+} detection using the same probe (Apt-Au NPs) and the same type of transducer (colorimetric) was achieved with sensitivities of 10nM to about 3 μM [58-61, 82]. While, for Pb^{2+} detection using the same probe (Apt-Au NPs & DNAzyme) for colorimetric type transducer gave almost similar sensitivity values [64, 65, 83]. In another study, the sensitivity could be down to 3nM [84]. On the other hand, using a different probe (Guanine - Quadruplex DNA aptamer, China) and fluorometric transducer resulted in

high sensitivity (0.4nM)[66].

Using three different probes based on three different types of transducers gave results from 10fM to 2nM in terms of sensitivity [75-77] for Bisphenol A detection. Moreover, with the highest sensitivity value (10fM) in Table 3 was also achieved in a very short time (10min) for Bisphenol A detection [75].

Some other aptamer-based nano-biosensor studies with sensitivity and response time values were exemplified in Table 3.

5. Conclusions

In this review, some improvements of biosensors and the contribution of nanotechnology to biosensors were discussed. Nanotechnology doped biosensors, which have just started to be used in the 90s, are still in their infancy and are precursors of the future technologies. With the effect of nanotechnology, the 4th generation of biosensors is called nano-biosensors. They are in use in industrial areas such as medicine, drug, food, agricultural, environmental etc. Due to nano-biosensors provide some advances such as frequency of usage, practical use and time-saving, high sensitivity, high selectivity, lower-cost, greater durability, reusability, simple instrumentation in the near future; there is no doubt that these technologies are going to continue to find their places with an increasing rate. On the other hand, aptamers provide specific contributions to detection of biologic components. Besides, using aptamers conjugated with nanomaterials is pretty new technology that should be developed and study on. Furthermore, when the studies on biosensors go down to pico, femto or maybe lower sizes. There will be techno-revolutions in those mentioned areas with the developments of science and technology.

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Table 3. Aptamer-based nano-biosensors studies

Analyte	Probe	Transducer type	Sensitivity	Response Time	Reference
Adenosine and Cocaine	Apt-Au NPs	colorimetric	from 0.3 to 2 mM	1 minute	[78]
Cocaine	Apt-Au NPs	colorimetric	about 20 µM	20 seconds	[53]
Adenosine	Apt-Au NPs	colorimetric	about 10µM	1 minute	[79]
Adenosine	Apt-Au NPs	SPR	from 1nM to 1 µM	30 minutes	[80]
Adenosine	Apt-Au NPs	electrochemical	0.18 nM	-	[54]
Cocaine	Apt-Au NPs	colorimetric	2µM	5 minutes	[81]
Cocaine	Apt-QD	fluorometric	50µM	1 minute	[55]
ATP	Apt-Au NPs	colorimetric	0.6 µM	-	[56]
ATP	Apt-Au NPs	colorimetric	10.0 nM	30 minutes	[57]
Cysteine	Apt-Au NPs & DNA-Au NP-Hg^{2+} aggregates	colorimetric	from 50 nM to 10 µM	-	[85]
Hg^{2+}	Apt-Au NPs	colorimetric	100 nM	-	[82]
Hg^{2+}	Apt-Au NPs	colorimetric	10 nM	-	[58]
Hg^{2+}	Apt-Au NPs	colorimetric	25 nM	-	[59]
Hg^{2+}	Apt-Au NPs	colorimetric	about 3 µM	5 minutes	[60]
Hg^{2+}	Apt-Au NPs	colorimetric	250 nM	-	[61]
K^{+}	Apt-Au NPs	colorimetric	about 20-2000 µM	1 minute	[62]
K^{+}	Apt-Au NPs	colorimetric	about 1 mM	4 minutes	[63]
Pb^{2+}	Apt-Au NPs & DNAzyme	colorimetric	from 0.1 to 4 µM	-	[64]
Pb^{2+}	Apt-Au NPs & DNAzyme	colorimetric	from 0.4 to 2 µM	-	[65]
Pb^{2+}	Apt-Au NPs & DNAzyme	colorimetric	from 0.1 to 2 µM	5 minutes	[83]
Pb^{2+}	Apt-Au NPs & DNAzyme	colorimetric	3 nM	5 minutes	[84]
Pb^{2+}	Guanine - Quadruplex DNA aptamer	fluorometric	0.4 nM	-	[66]
As(III)	Apt-Au NPs	colorimetric	40 ppb	-	[86]
As(III)	Apt-Au NPs	resonance scattering	0.6 ppb	-	[86]
Ethanolamine (EA)	Guanine-rich apt. DNA	electrochemical	0.08 nM	-	[67]
K^{+}	Guanine-rich apt. DNA	electrochemical	0.1 nM	-	[68]
Organophosphorus Pesticides	Apt-Au NPs	colorimetric	0.143-2.696 ppm	-	[69]
Malathion	Apt-Au NPs	colorimetric	0.06 pM	-	[70]
Acetamiprid	The ABA (acetamiprid binding aptamer)-stabilized Au NPs	resonance scattering	1.2 nM	10 minutes	[71]
Oxytetracycline	DNA aptamer-templated silver nanoclusters (AgNCs)	fluorometric	0.1 nM	180 minutes	[72]
Fluoroquinolone antibiotics	DNA Aptamers	fluorometric	0.1–56.9 nM	-	[73]
Progesterone	DNA Aptamers	electrochemical	0.90 ng/mL	-	[74]
Bisphenol A (BPA)	ds DNA-embedded Au/Ag core–shell NPs	surface-enhanced raman scattering	10fM	10 minutes	[75]
Bisphenol A (BPA)	Au NPs activated ZnO nanopencils	photoelectrochemical(PEC)	0.5 nM	-	[76]
Bisphenol A (BPA)	anti-BPA apt. and molybdenum carbide nanotubes	fluorometric	2 nM	-	[77]