



Development of novel assessment system for assessing and monitoring the current situation of water efficiency practices and components at schools

Okullarda su verimliliği faaliyetlerinin mevcut durumunun değerlendirilmesi ve izlenmesi için özgün mevcut durum değerlendirme sisteminin geliştirilmesi

Mahmut Fırat^{1*} , Furkan Güngör¹ , Cansu Bozkurt²

¹Department of Civil Engineering, Faculty of Engineering, İnönü University, Malatya, Türkiye.
mahmut.firat@inonu.edu.tr, furkangngrr@gmail.com

²Construction Program, Technical Vocational Schools, Ardahan University, Ardahan, Türkiye.
cansubozkurt@ardahan.edu.tr

Received/Geliş Tarihi: 06.10.2025
Accepted/Kabul Tarihi: 11.02.2026

Revision/Düzeltilme Tarihi: 22.12.2025

doi: 10.65206/pajes.02491
Research Article/Araştırma Makalesi

Abstract

Climate change, the decrease in clean water resources and the increase in water demand necessitate systematic implementation of water efficiency practices. The sustainability of water efficiency practices in high-consumption users should be monitored. The aim of this study is to develop a comprehensive and holistic assessment system to monitor the current level of water efficiency practices at schools. Assessment components were defined within the scope of training and capacity development, maintenance, control, water consumption and efficiency monitoring. An assessment scale between 1 and 5 was defined to evaluate the current level of implementation of components. The assessment system was implemented based on on-site inspections at a total of 12 schools. The assessment components under training and capacity building and water consumption analysis and monitoring are generally insufficient performance. The components under control and maintenance are generally above average performance. Awareness, training and event organization practices within the scope of water efficiency are insufficient. The proposed assessment system should be applied to schools annually. This assessment system will make significant contributions to identifying weaknesses in water efficiency, monitoring the improvement of weaknesses over time, and evaluating the impact of practices on water efficiency.

Keywords: Urban water efficiency, Water efficiency in schools, Water efficiency evaluation system, Water management.

Öz

Değişen iklim koşulları ve su talebinin artması kentsel su yönetiminde su verimliliğini zorunlu kılmaktadır. Özellikle okullar gibi yüksek tüketimli kullanıcılarda bu durum daha da önemlidir. Yüksek tüketimli kullanıcılarda su verimliliği faaliyetlerinin sürdürülebilirliği izlenmelidir. Bu çalışmada okullarda su verimliliği faaliyetlerinin mevcut uygulama düzeylerinin izlenmesi için değerlendirme sisteminin geliştirilmesi amaçlanmıştır. Bunun için, kapasite geliştirme, bakım, kontrol, denetim, su tüketim izleme ve verimlilik izleme kapsamında değerlendirme bileşenleri tanımlanmıştır. Bu bileşenlerin okullarda mevcut uygulama düzeyini değerlendirmek için 1 ile 5 arasında puanlandırma sistemi önerilmiştir. Değerlendirme sistemi toplam 12 okulda yerinde yapılan incelemelere göre uygulanmıştır. Pilot okullarda genel olarak eğitim ve kapasite geliştirme ve su tüketim analiz ve izleme altındaki değerlendirme bileşenleri yetersiz düzeydedir. Bununla birlikte, denetim, kontrol ve bakım altındaki bileşenler ise genel olarak ortalamanın üzerindedir. Özellikle okullarda su verimliliği kapsamında farkındalık, bilgilendirme, eğitim ve etkinlik düzenleme faaliyetlerinin yetersiz düzeyde olduğu görülmüştür. Bu çalışmada önerilen su verimliliği değerlendirme sistemi okullarda yıllık olarak uygulanmalıdır. Bu değerlendirme sistemi okullarda su verimliliği kapsamında zayıf yönlerin belirlenmesi, zayıf yönlerin zaman içinde iyileşme durumunun izlenmesi, etkinliklerin su verimliliği üzerindeki etkisinin değerlendirilmesi açısından önemli katkılar sunacaktır.

Anahtar Kelimeler: Kentsel su verimliliği, Okullarda su verimliliği, Su verimliliği değerlendirme sistemi, Su yönetimi.

1 Introduction

Water efficiency in urban infrastructure systems and end users should be ensured for sustainable management of water resources. Preventing leaks in transmission line and distribution networks plays a critical role in ensuring the efficiency of existing freshwater resources [1]. Moreover, residential and non-residential (schools, industry, public, etc.) end users have the potential to make significant contributions to water efficiency. Especially, planning water efficiency practices, choosing new technology equipment that provides water efficiency and their systematic implementation are quite important for high-consumption users [2]-[4]. Such practices and events will contribute more if adopted as a general

principle. In this context, the Türkiye Water Efficiency Mobilization was launched in Türkiye in 2023 and the water efficiency strategy document covering the years 2023-2033 was published. This strategy document includes water efficiency targets, actions and water efficiency recommendations for all sectors (urban, agriculture, industry, tourism, education, etc.). Later, the Water Efficiency Regulation was published on December 27, 2024. This regulation covers the establishment of water efficiency units for all sectors, analysis of the current situation, creation, implementation and reporting of water efficiency plans. The practices defined in this regulation are planned to contribute the water efficiency, especially in sectors with high consumption (educational institutions, hotels, industrial, schools, public buildings, etc.).

*Corresponding author/Yazışılan Yazar

The awareness and knowledge level of students and teachers is quite important to ensure water efficiency in schools. For this purpose, practices and trainings need to be planned within the scope of water efficiency and the importance of water. Systematic training and awareness practices, analysis of consumption, and creation of maintenance and inspection programs will contribute to achieving water efficiency in a wide range of populations [5]-[7]. The studies published in the literature include the analysis of previous water consumption data in schools and pilot-level applications [7]-[13]. It was proposed a quantitative evaluation system that focuses on water use in primary schools and promotes water conservation. Annual water consumption per person in pilot schools, usage in swimming pools and in outdoor were analyzed using statistical methods [14]. The model was proposed for water use in schools using the regression method by considering annual water usage data in a total of 375 schools [15]. A methodology was developed to define water consumption behavior in primary schools using long-term online monitoring data [16]. The various practical applications and improvement methods were implemented to save water. The study suggested the methods of collecting rainwater with small additions to roofs, placing water tanks in the school garden for agricultural practices, and choosing plants that consume less water can contribute to water saving [17]. It was examined water consumptions in secondary schools in Australia and identified improvements that could be made to increase water efficiency. Water consumption per capita in 70 schools was calculated. Inspections were carried out in schools to achieve savings and total water use decreased by 13% in the following 12-month period. It was emphasized that larger-scale inspections and monitoring systems should be established to increase water efficiency and policies encouraging water saving should be widespread in schools [18]. It was suggested sustainability methods, guide documents and studies that should be implemented in future school designs in the interior and exterior design of schools to ensure sustainable water management [2]. It was proposed rational water use indicators such as water consumption per student for pilot public schools [19]. The importance of training for sustainable water use and analysis of trends in water use around the world was stated. The study suggested that awareness campaigns in schools regarding water consumption should be increased. Moreover, the policies should be developed to reduce the negative effects of free water [9]. Water efficiency and consumption indicators in schools were evaluated based on monthly water consumption data from past periods. The assessment system or index that enables the improvement, prevention and monitoring of water efficiency has not been proposed. In literature, various assessment systems have been proposed to monitor data quality and assess the current implementation level of urban water management components. These systems generally cover infrastructure systems, leakage management, water balance management, urban water efficiency, non-revenue water management and wastewater treatment management at water distribution system and wastewater treatment plant scale [20]. A novel assessment model was proposed based on a scoring scale to evaluate the applicability of water loss management practices, to assess the data quality and current implementation level of management components [21]. A comprehensive framework was developed based on a scoring table to evaluate the current level of application of methods applied in the management of leaks occurring in drinking water infrastructure systems [22]. It was proposed an

assessment framework that evaluates the data quality and current application levels of management components in wastewater treatment plants and recommends the most appropriate improvement method according to the current situation [23]. An assessment methodology was developed to analyze the current implementation level of data that have been used in water loss management [24].

On the other hand, the environmental, energy, waste management and economic indicators were generally considered in the analysis and monitoring of efficiency in schools. However, a comprehensive current status assessment system that directly considers the components of water efficiency monitoring in schools, training and practice planning, and maintenance and control of installations and equipment in indoor and outdoor, has not been defined. In summary, an assessment system that provides a comprehensive and holistic analysis and monitoring of water efficiency practices in schools has not been proposed. However, water efficiency studies and practices should be carried out systematically and sustainably. Moreover, water consumptions in schools should be monitored by evaluating water efficiency practices and practices, by considering the awareness and consciousness-raising practices, training, maintenance and inspection. Therefore, an integrated assessment system is needed that takes into account all components and actors within the scope of water efficiency in schools and provides comparative evaluation. The research question of this study is that Could an evaluation system be developed that takes into account holistically and enables monitoring of practices that contribute to water efficiency in schools? Is it possible to evaluate water efficiency practices in schools separately in the developed evaluation system?

This study aimed to develop a novel assessment system for the analysis and monitoring of current implementation levels of water efficiency practices in schools. This study basically includes the steps of determining water efficiency practices in schools, building an assessment system to monitor the current status of water efficiency practices, and testing the assessment system in pilot schools. The comprehensive and integrated assessment system proposed for monitoring water efficiency in schools is novel. In addition, the definition of the components that cover all aspects of water efficiency practices in schools in this assessment system and scoring structure defined for the components contribute significantly to the novelty of the study.

2 Methodology

An *assessment system* was developed to evaluate the current status of water efficiency practices in schools and monitor the sustainability. This evaluation system covers all aspects of water efficiency practices in schools. The assessment system consists of 3 water efficiency main practices which are "Training and Capacity Building", "Water Consumption Analysis and Monitoring", and "Control and Maintenance". A category of sub-practices under each main practice is defined (Figure 1). Additionally, "Assessment Components" that enable the evaluation of the current status of water efficiency practices of schools under sub-practices were determined.

An assessment scale between points 1 and 5 was defined to evaluate the components in schools and reveal the current status within the scope of water efficiency. This assessment scale consists of a total of five classes that are, Point 1 (Low Performance), Point 2 (Inadequate Performance), Point 3 (Moderate Performance), Point 4 (High Performance) Point 5 (Quite High Performance).

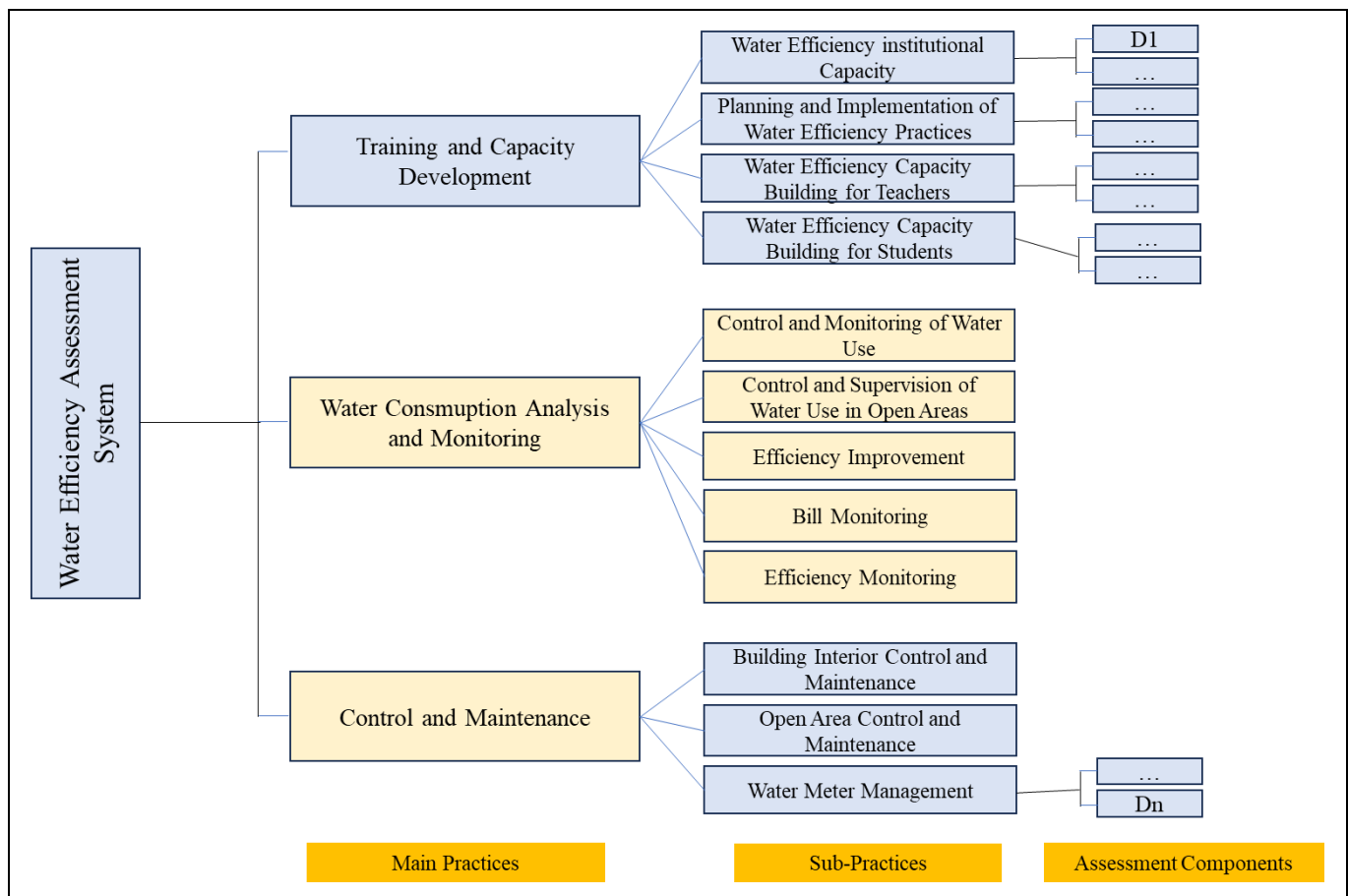


Figure 1. Assessment system for monitoring water efficiency practices at schools.

The current level of each component will be determined according to the current status in schools. Components with scores of 1, 2, and 3 constitute weaknesses in the scope of water efficiency. These components should first be evaluated in order to improve the current situation of water efficiency practices in schools.

On the other hand, components with scores 4 and 5 constitute strengths in terms of water efficiency. The current status of these components should be preserved. In the water efficiency assessment system, the first main practice of "Training and Capacity Development" mainly includes assessment components of capacity development and training (Table 1). Training is one of the most fundamental components in ensuring water efficiency and sustainability. The capacity development practices play an important role in raising awareness. Therefore, these components were considered in this assessment system.

The sub-practice of "Water Efficiency Institutional Capacity" basically includes the establishment of teams and clubs that will ensure the participation of students within the scope of water efficiency, planning and reporting of practices. These components specifically assess the involvement of students in water efficiency practices and the current implementation level of practices planned with student participation. The sub-practice of "Planning and Implementation of Water Efficiency Practices" basically covers increasing the awareness level of students for sustainable water efficiency and organizing

practices that will ensure student participation. Especially, practices that attract students' attention, ensure their active participation, and contribute to the emergence of creativity play an important role in increasing the level of awareness of students. The sub-practice of "Water Efficiency Capacity Development for Teachers" basically includes the components of increasing the knowledge level of teachers within the scope of water efficiency and saving, providing information about the journey of water, and participation in practices organized by stakeholder institutions. The sub-practice of "Water Efficiency Capacity Development for Students" basically covers the components of increasing the knowledge level of students within the scope of water efficiency and saving, providing information about the journey of water, and carrying out joint practices and projects with stakeholder institutions. The second main practice "Water Consumption Analysis and Monitoring" mainly includes the assessment components of control and monitoring of water use in building and in open areas, bill monitoring, efficiency improvement and monitoring (Table 2).

The sub-practice of "Control and Monitoring of Water Use" includes monitoring and managing water use and the current status of the equipment in water use areas (toilets, laboratories, cafeterias, inside buildings) at school. The sub-practice of "Control and Supervision of Water Use in Open Areas" covers monitoring water use in open areas at school and monitoring and managing the current status of the equipment in water use areas.

Table 1. Assessment components under the main practice of “Training and Capacity Development”.

Assessment Components	ID	Assessment Scale				
		1	2	3	4	5
Water Efficiency Institutional Capacity						
Establishing a water efficiency team	WEC1	NA		Present. Inactive		Present
Establishing a water efficiency club	WEC2	NA		Present. Inactive		Present
Representation rate of classes in water efficiency club	WEC3	NA	<25%	25-50%	50-75%	>75%
Rate of students participating in water efficiency club	WEC4	NA	<25%	25-50%	50-75%	>75%
Frequency of organizing water efficiency club events	WEC5	NA	12 months	6 months	3 months	<3 months
Rate of teachers participating in water efficiency club	WEC6	NA	<25	25-50	50-75	>75
Frequency of reporting water efficiency club activities	WEC7	NA	12 months	6 months	3 months	<3 months
Annually planned water efficiency competitions	WEC8	NA	Composition	Composition, Poetry	Composition, Poetry, Painting	Poetry, Painting, Theatre
Frequency of sharing about water efficiency on the school website	WEC9	NA	12 months	6 months	3 months	<3 months
Inclusion of water efficiency in the curriculum	WEC10	NA		Partially		Available
Frequency of reporting water efficiency activities	WEC11	NA	12 months	6 months	3 months	<3 months
Planning and Implementation of Water Efficiency Practices						
Creation of water efficiency labels in water usage areas	PWE1	NA	WC	WC and Landscape	WC, Landscape and Canteen	WC, Landscape and Canteen, Gym
Update of water board/corner for water efficiency	PWE2	NA	12 months	6 months	3 months	<3 months
Frequency of publishing water efficiency events in the water board	PWE3	NA	12 months	6 months	3 months	<3 months
Frequency of organizing painting, composition and poetry competitions	PWE4	NA	12 months	6 months	3 months	<3 months
Frequency of organizing slogan and cartoon contests	PWE5	NA	> 24 months	24 months	12 months	<12 months
Frequency of theatre activity for water efficiency	PWE6	NA	> 24 months	24 months	12 months	<12 months
Organizing a special presentation event for world water day	PWE7	NA	Teachers	Stakeholder Institutions	Researchers from the University	Water Efficiency Workshop
Frequency of organizing events with stakeholder institutions	PWE8	NA	>12 months	12 months	6 months	3 months
Frequency of preparing posters, brochures and information notes	PWE9	NA	>12 months	12 months	6 months	3 months
Frequency of creating corridors on water efficiency	PWE10	NA	>12 months	12 months	6 months	3 months
Frequency of showing water efficiency promotional films	PWE11	NA	>12 months	12 months	6 months	3 months
Frequency of organizing training for the maintenance team	PWE12	NA	>12 months	12 months	6 months	3 months
Water Efficiency Capacity Development for Teachers						
Percentage of teachers who have knowledge about the importance of water	WET1	NA	<25%	25-50%	50-75%	>75%
Percentage of teachers having knowledge about the water resources	WET2	NA	<25%	25-50%	50-75%	>75%
Percentage of teachers having knowledge about the water efficiency	WET3	NA	<25%	25-50%	50-75%	>75%
Percentage of teachers having knowledge about efficient water use	WET4	NA	<25%	25-50%	50-75%	>75%
Percentage of teachers having knowledge about the journey of water	WET5	NA	<25%	25-50%	50-75%	>75%
Percentage of teachers having knowledge about the water footprint	WET6	NA	<25%	25-50%	50-75%	>75%
Frequency of water efficiency training activity for teachers	WET7	NA	> 24 months	24 months	12 months	<12 months
Frequency of teachers' participation in external water efficiency training	WET8	NA	>12 months	12 months	6 months	3 months
Frequency of teachers preparing water efficiency projects with stakeholders	WET9	NA	> 24 months	24 months	12 months	<12 months
Frequency of teachers examining water efficiency practices	WET10	NA	> 24 months	24 months	12 months	<12 months
Frequency of school management in informing about water efficiency	WET11	NA	>12 months	12 months	6 months	3 months
Frequency of water efficiency briefings by external experts	WET12	NA	>12 months	12 months	6 months	3 months
Water Efficiency Capacity Development for Students						
Percentage of students having knowledge about the importance of water	WES1	NA	<25%	25-50%	50-75%	>75%
Percentage of students having knowledge about the water resources	WES2	NA	<25%	25-50%	50-75%	>75%
Percentage of students having knowledge about the water efficiency	WES3	NA	<25%	25-50%	50-75%	>75%
Percentage of students having knowledge about efficient water use	WES4	NA	<25%	25-50%	50-75%	>75%
Percentage of students who are aware of reporting broken taps	WES5	NA	<25%	25-50%	50-75%	>75%
Percentage of students having knowledge about the journey of water	WES6	NA	<25%	25-50%	50-75%	>75%
Percentage of students having knowledge about the water footprint	WES7	NA	<25%	25-50%	50-75%	>75%
Frequency of water efficiency training for students	WES8	NA	> 24 months	24 months	12 months	<12 months
Frequency of students' participation in external water efficiency training	WES9	NA	> 24 months	24 months	12 months	<12 months
Frequency of students examining water efficiency practices	WES10	NA	> 24 months	24 months	12 months	<12 months
Frequency of water efficiency information for parents at school	WES11	NA	> 24 months	24 months	12 months	<12 months
Frequency of water efficiency briefing to students by external experts	WES12	NA	> 24 months	24 months	12 months	<12 months

NA: Not available.

Table 2. Assessment components under the main practice of “Water Consumption Analysis and Monitoring”.

Assessment Components	ID	Assessment Scale				
		1	2	3	4	5
Control and Monitoring of Water Use						
Average consumption per capita	CMW1	>4 m³	3 m³- 4 m³	2 m³ - 3 m³	1 m³ - 2 m³	<1 m³
Frequency of checking water usage areas in the building	CMW2	NA	6 months	3 months	1 month	<1 month
Frequency of monitoring meter reading status	CMW3	NA	>6 months	6 months	3 months	1 month
Frequency of monitoring water usage volume	CMW4	NA	6 months	3 months	1 month	<1 month
Frequency of analysis of changes in water use	CMW5	NA	6 months	3 months	1 month	<1 month
Frequency of analysis of water usage per student	CMW6	NA	>6 months	6 months	3 months	1 month
Frequency of fire hydrant use in the building	CMW7	<1 ay	1-3 months	3 -6 months	6-12 months	>12 months
Frequency of monitoring water usage in laboratories	CMW8	NA	6 months	3 months	1 month	<1 month
Frequency of monitoring water usage in the cafeteria	CMW9	NA	6 months	3 months	1 month	<1 month
Monitoring water usage in the canteen	CMW10	NA	6 months	3 months	1 month	<1 month
Sensor taps usage rate	CMW11	NA	<25%	25-50%	50-75%	>75%
Status of guidance for building cleaning and washing policy	CMW12	NA		Partially		Present
Control and Maintenance of Water Use in Open Areas						
Water efficiency applications in landscape (1: armature, 2: drip irrigation, 3: rainwater harvesting, 4: water sensitive plant)	CMA1	NA	1	1 and 2	1, 2 and 3	1, 2, 3 and 4
Control frequency of water use in outdoor	CMA2	NA	6 months	3 months	1 month	<1 month
Frequency of measurement of water use in landscape	CMA3	NA	6 months	3 months	1 month	<1 month
Seasonal adjustment frequency of landscape irrigation	CMA4	NA	>6 months	6 months	3 months	1 month
Innovative irrigation system in landscape	CMA5	NA	Manual, sprinkler	Manual, drip	Automatic, sprinkler	Automatic, drip
Landscape rate with irrigation based on weather conditions	CMA6	NA	<25%	25-50%	50-75%	>75%
Water usage rate per unit area	CMA7	NA	>6 months	6 months	3 months	<3 months
Frequency of monitoring water usage in the gym	CMA8	NA	> Monthly	Monthly	Weekly	< Weekly
Valve/plumbing inspection frequency	CMA9	NA	> Monthly	Monthly	Weekly	< Weekly
Water sensitive plant usage rate	CMA10	NA	<25%	25-50%	50-75%	>75%
Knowledge level about rainwater harvesting	CMA11	NA	Legislation	Legislation and methods	Legislation, methods, planning	Legislation, methods, planning, application
Knowledge level about rainwater harvesting systems	CMA12	NA	Legislation	Building roof applications	Building roof, basement floor application	Building roof, basement floor application, automation
Efficiency Improvement						
Frequency of efficiency analysis and monitoring	EFD1	NA	12 months	6 months	3 months	1 month
Frequency of monitoring water efficiency in open area	EFD2	NA	12 months	6 months	3 months	1 month
Frequency of water efficiency monitoring in building	EFD3	NA	12 months	6 months	3 months	1 month
Rainwater harvesting application status	EFD4	NA		Partially		Present
Water efficiency cost analysis status	EFD5	NA		Partially		Present
Analysis status of water efficiency gains	EFD6	NA		Partially		Present
Water saving equipment ratio in sinks and taps	EFD7	NA	<25%	25-50%	50-75%	>75%
Equipment ratio that reduces water consumption in flushes	EFD8	NA	<25%	25-50%	50-75%	>75%
Adequacy of the number of repair and maintenance teams	EFD9	NA		Partially		Fully
Repair and maintenance equipment capacity adequacy	EFD10	NA		Partially		Fully
Water saving equipment rate in open areas	EFD11	NA	<25%	25-50%	50-75%	>75%
Urinal flush sensor utilization rate	EFD12	NA	<25%	25-50%	50-75%	>75%
Bill Monitoring						
Activities to reduce water bills	BMN1	NA		Partially		Yes
Frequency of comparing invoices with previous periods	BMN2	NA	>6 months	6 months	3 months	1 month
Compliance of invoices with usage habits	BMN3	NA		Partially		Available
Compliance of bills with water saving policies	BMN4	NA		Partially		Available
Frequency of efficiency analysis of water saving equipment	BMN5	NA	>6 months	6 months	3 months	1 month
Efficiency Monitoring						
The status of implementing staff efficiency studies	EFM1	NA		Partially Present		Present
Efficiency policy update status	EFM2	NA		Partially Present		Present
Implementation status of activities based on data analysis	EFM3	NA		Partially Present		Present
The performance improvement status of efficiency policy	EFM4	NA		Partially Present		Present
Use of metrics in monitoring water efficiency	EFM5	NA		Partially Present		Present
Efficiency of rainwater harvesting	EFM6	NA		Partially Present		Present
Monitoring of rainwater harvesting	EFM7	NA		Partially Present		Present
Monitoring rainwater harvesting costs and benefits	EFM8	NA		Partially Present		Present
The ratio of rainwater harvesting to water demand	EFM9	NA	<25%	25-50%	50-75%	>75%

The sub-practice of “Efficiency Improvement” mainly includes the components such as the policy of improving water saving and efficiency in open and closed areas of the school, the maintenance and control strategy of equipment, and the policy of selecting equipment that reduces water consumption.

The sub-practice of “Efficiency Monitoring” mainly includes the components such as evaluating the impact of water efficiency practices, awareness training, and equipment management on water efficiency at school. The sub-practice of “Bill Monitoring” covers the components such as invoice compliances and analysis of bill. The sub-practice of “Control and Maintenance”

include assessment components within the scope of building interior and open areas control and inspection, and meter management (Table 3). The sub-practice of “Building Interior Control and Maintenance” covers the collection, monitoring, control, maintenance and repair of water usage and equipment inventory information in closed areas (toilet, laboratory, cafeteria, inside the building), and the creation of maintenance and monitoring forms and reports.

Table 3. Assessment components under the main practice of “Control and Maintenance”.

Assessment Components	ID	Assessment Scale				
		1	2	3	4	5
Building Interior Control and Maintenance						
Frequency of piping and equipment data updates in the building	BCM1	NA	12 months	6 months	3 months	1 month
Frequency of inspection and audit of urinals	BCM2	NA	12 months	6 months	3 months	1 month
Frequency of control and inspection of flush tanks in toilets	BCM3	NA	12 months	6 months	3 months	1 month
Frequency of control and inspection of taps	BCM4	NA	12 months	6 months	3 months	1 month
Frequency of leakage control and inspection of installations and pipes	BCM5	NA	12 months	6 months	3 months	1 month
Frequency of water use control in cleaning classrooms	BCM6	NA	3 months	1 month	Weekly	Daily
Consideration of water efficiency in classroom cleaning	BCM7	NA		Partially		Present
Tap and siphon repair time	BCM8	NA	2-4 weeks	1-2 weeks	1 week	1 Day
Frequency of reporting of installation inspections and repairs	BCM9	NA	>6 months	6 months	3 months	Monthly
Frequency of checking leakage status of taps	BCM10	NA	>2 weeks	1-2 weeks	Weekly	< 1 week
Monitoring form for control of equipment in building	BCM11	NA	Siphons	Siphons and Sinks	Siphons, Sinks, Toilets	All installations
Monitoring form for repair of equipment in building	BCM12	NA	Siphons	Siphons and Sinks	Siphons, Sinks, Toilets	All installations
Status of equipment required for plumbing repair in building	BCM13	NA		Basic Equipment		All Equipment
Open Area Control and Maintenance						
Pipe and equipment data update frequency in open area	ACM1	NA	>6 months	6 months	3 months	1 months
Layout plan of pipes and equipment in open area	ACM2	NA		Partially		Available
Frequency of leak checks for installations and pipes	ACM3	NA	>6 months	6 months	3 months	1 months
Frequency of leak check for fire hydrants/connections	ACM4	NA	>6 months	6 months	3 months	1 months
Frequency of checking leakage status of installations in open areas	ACM5	NA	>6 months	6 months	3 months	1 months
Open area installation repair time	ACM6	NA	2-4 weeks	1-2 weeks	1 week	1 Day
Reporting frequency of inspections and repairs in open area (	ACM7	NA	>6 months	6 months	3 months	1 month
Monitoring form for control of equipment in open area	ACM8	NA		Water usage areas		All installations
Monitoring form for repair of equipment in open area	ACM9	NA		Water usage areas		All installations
Water Meter Management						
Frequency of checking the physical condition of water meters	WMM1	NA	>6 months	6 months	3 months	<3 months
Protection status to prevent meters from freezing	WMM2	NA		Partially		Yes
Water meter accuracy*	WMM3	R40	R50	R80	R100	R160
Water meter installation location suitability	WMM4	NA		Partially Suitable		Suitable

*R denotes the accuracy of the counters. Counters with a high R-value are more accurate.

The sub-practice of “Open Area Control and Maintenance” includes the collection of inventory information, monitoring, control, maintenance and repair of water usage and equipment in open areas, and the creation of maintenance and monitoring forms and reports. The sub-practice of “Water Meter Management” basically includes the control and management components of meters.

3 Analysis and results

The water efficiency assessment system in schools developed in this study was tested in a total of 12 pilot schools, in Malatya located at the east region of Türkiye, based on-site inspections and evaluations. The water requirement of Malatya province is provided by a water source with an average flow rate of 3,200 l/s. Pilot schools were determined by considering the size, physical conditions, student profiles, student distribution and age ranges of the schools Table 4. In this study, three different types of schools that are four primary schools, four secondary schools and four high schools located in the city center were selected. In primary schools, the student age range varies between 7 and 10 years. The age range of students in secondary schools is between 11 and 14, and in high schools it is between 14 and 18. Malatya province is one of the cities where the earthquake centered in Kahramanmaraş occurred on February 6, 2023. Due to the earthquake, water resources were damaged, pollution was observed and a decrease in flow occurred. In

addition, the earthquake has caused failure rates in the elements serving the transmission and distribution system to reach serious levels. As a result, leaks have increased and more efficient use of water resources has become necessary. Water saving becomes even more important for users with high water consumption in urban areas. Water efficiency practices, especially at schools, make a significant contribution to the efficient use of existing resources. The water efficiency assessment system was implemented at 12 schools, where on-site examination was carried out and each variable was scored in accordance based on current the situation. The current status of the assessment components under the main practice of “Training and Capacity Development” at the pilot schools are presented in Table 5.

Under the WEC sub-practice, the current implementation level of establishment of water efficiency teams and club components are insufficient at many schools. Moreover, the active participation of students and teachers in practices, the planning, implementation and reporting of practices are also insufficient. It is seen that the implementation of the components is at good level only at the school coded School11. In this sub-component category, the WEC10 component (Including Water Efficiency in the Curriculum) is at an average level across schools. However, other practices are generally in the low performance class. The current implementation levels of the assessment components under the PWE should be

improved in order to ensure water efficiency at schools, create water saving awareness, and ensure that students take a more active role in water efficiency practices. Under PWE, the current implementation levels of components such as planning water

efficiency practices (painting, composition, poetry, cartoon competitions, theater) and conducting awareness-raising practices for students are inadequate at many schools.

Table 4. Characteristics of pilot schools.

School Feature	School 1	School2	School3	School4	School5	School6	School7	School8	School9	School10	School11	School12
School Category	Primary	Primary	Primary	Primary	Middle	Middle	Middle	Middle	High	High	High	High
Number of Students	490	962	858	665	620	715	322	621	1,017	460	564	569
Number of Teachers	72	56	46	32	77	5	30	36	78	42	57	47
Number of Staff	8	10	10	6	9	24	6	6	8	6	8	17
Total Number of People	570	1,028	914	703	706	744	358	663	1,103	508	629	633
Year of Construction	2015	2014	2010	2019	2007	2019	2008	2015	2015	1989	2019	2019
Canteen (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Dining Hall Capacity	NA	NA	NA	NA	NA	NA	NA	NA	100	NA	208	200
Closed Area(m ²)	6,080	1,500	760	727	5,000	1,900	2,280	5,000	7,910	3,500	5,000	4,764
Open Area(m ²)	10,500	6,000	1,810	2,300	3,700	1,668	1,500	2,000	9,859	25,000	7,000	9,000
Landscape Area(m ²)	3,318	6,000	0	150	1,200	670	700	1,000	1,010	20,000	0	2,000
Number of Beds in Hostel	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	208	NA
Number of WC	58	16	30	14	34	40	32	32	74	26	16	39
Number of Sinks	58	32	30	14	50	40	40	32	16	13	16	39

Table 5. Current status of assessment components under the main practice of “Training and Capacity Development” at pilot schools.

Criteria	School1	School2	School3	School4	School5	School6	School7	School8	School9	School10	School11	School12
WEC1	1	1	5	1	1	5	5	5	1	5	1	1
WEC2	1	5	1	1	3	1	1	1	1	1	5	1
WEC3	1	1	1	1	2	1	1	1	1	1	5	1
WEC4	1	1	1	1	2	1	1	1	1	1	5	1
WEC5	1	2	1	1	1	1	1	1	1	1	4	1
WEC6	1	2	1	1	2	1	1	1	1	1	3	1
WEC7	1	2	1	1	5	1	1	1	1	1	4	1
WEC8	1	1	3	1	1	1	1	1	3	4	4	1
WEC9	2	2	2	2	1	1	1	1	1	2	1	1
WEC10	3	3	3	5	3	3	3	3	3	3	3	5
WEC11	2	2	2	3	1	2	1	1	2	2	4	1
PWE1	2	2	2	5	2	1	1	2	2	2	2	2
PWE2	1	2	1	3	2	1	2	1	1	2	4	1
PWE3	1	2	1	3	1	1	2	1	1	2	4	1
PWE4	1	1	2	2	2	1	1	1	2	2	2	2
PWE5	1	1	1	4	1	1	1	1	1	1	4	1
PWE6	1	1	1	4	1	1	1	1	1	1	1	1
PWE7	1	2	2	3	2	1	2	1	2	2	2	1
PWE8	1	1	1	3	3	2	1	1	1	1	1	1
PWE9	1	1	1	3	3	1	1	1	1	2	4	1
PWE10	1	1	1	3	1	1	1	1	1	1	4	1
PWE11	1	1	3	3	3	1	1	1	1	1	3	1
PWE12	1	1	3	1	1	1	1	1	1	1	1	1
WET1	5	5	5	5	3	4	3	5	5	5	5	5
WET2	5	5	5	5	3	4	3	5	5	5	5	4
WET3	5	5	5	5	1	4	3	5	5	5	5	4
WET4	5	5	5	5	3	4	3	5	5	5	5	4
WET5	5	5	5	5	2	4	3	5	5	5	5	4
WET6	5	5	4	4	2	3	3	5	5	1	4	1
WET7	3	1	1	1	1	1	1	1	1	1	1	1
WET8	2	1	1	1	2	1	3	1	2	1	1	1
WET9	1	1	1	1	1	1	1	1	1	1	1	1
WET10	1	1	1	1	1	1	1	1	1	1	3	2
WET11	1	1	4	5	3	3	2	3	3	2	5	1
WET12	2	1	1	1	3	1	1	1	2	1	1	1
WES1	3	4	3	3	1	3	2	4	4	5	5	4
WES2	3	4	3	3	1	3	2	4	4	5	5	4
WES3	3	4	3	3	1	3	2	4	4	5	5	4
WES4	3	4	3	3	2	3	2	4	4	5	5	4
WES5	5	5	4	3	2	5	5	5	4	5	5	4
WES6	3	4	2	2	1	3	2	4	4	5	4	3
WES7	3	4	2	2	1	3	2	4	3	1	4	1
WES8	3	1	1	1	1	1	1	1	1	1	1	1
WES9	2	1	1	1	1	1	1	1	1	1	1	1
WES10	1	1	1	1	1	1	1	1	1	1	1	1
WES11	1	3	1	4	3	1	1	3	1	2	5	1
WES12	2	1	1	1	1	1	1	1	1	1	1	1

The current level of implementation of the components at School4 and School11 schools is above average or close to the good performance class. Inadequate components that are the creating water saving awareness and consciousness among students and teachers and increasing the level of water efficiency knowledge create serious pressure on excessive water use or inefficient use of water at schools.

Under WET, teachers' participation in training and projects within the scope of water efficiency is questioned. In addition, awareness and knowledge level components about the importance of water, water resources, water efficiency and the journey of water are assessed. It is observed that at pilot schools, especially teachers' awareness and knowledge levels about water resources, the importance of water, water efficiency and saving, and the journey of water are at good or quite good level. Having these components at a good level will make a significant contribution to teachers' planning and implementation of water efficiency practices. It will also support the transfer of water efficiency to students more

effectively. On the other hand, teachers' participation in water efficiency training, project production and examination of water efficiency practices are generally insufficient or at low class. These components need to be improved for more effective and sustainable water efficiency. Under WES, students' participation in training and projects within the scope of water efficiency is questioned.

Moreover, awareness and knowledge level components about the importance of water, water resources, water efficiency and the journey of water are also assessed. It is observed that at pilot schools, especially teachers' awareness and knowledge levels about water resources, the importance of water, water efficiency and saving, and the journey of water are at moderate class. On the other hand, students' participation in water efficiency training and their examination of water efficiency practices are generally insufficient or at low level. The current status (scores) of the assessment components under the main practice of Water Consumption Analysis and Monitoring at the pilot schools are presented in Table 6.

Table 6. Current status of assessment components under the main practice of "Water consumption analysis and monitoring" at pilot schools.

Criteria	School1	School2	School3	School4	School5	School6	School7	School8	School9	School10	School11	School12
CMW1	1	3	4	2	3	2	3	4	1	1	1	1
CMW2	4	4	2	4	5	5	5	4	4	4	5	5
CMW3	5	5	5	5	5	5	5	5	5	5	5	5
CMW4	4	4	4	4	4	4	4	4	3	4	4	4
CMW5	4	4	4	4	5	4	4	4	4	2	4	4
CMW6	5	5	5	5	5	5	5	5	5	2	5	5
CMW7	5	5	5	5	3	5	5	5	5	5	5	5
CMW8	1	1	1	1	1	1	1	1	1	1	1	1
CMW9	1	1	1	1	1	1	1	1	1	4	1	4
CMW10	5	5	5	1	5	5	5	5	5	5	1	5
CMW11	3	1	1	1	1	1	1	1	1	1	5	1
CMW12	1	1	5	5	1	5	5	5	1	1	1	5
CMA1	3	1	1	1	1	3	1	4	3	1	1	3
CMA2	4	4	4	4	1	5	4	1	5	2	4	5
CMA3	3	1	1	1	1	1	1	1	1	1	1	1
CMA4	5	1	1	1	1	1	1	5	5	5	1	5
CMA5	3	1	1	1	1	3	1	3	3	1	1	3
CMA6	1	1	1	1	1	1	1	1	1	1	1	1
CMA7	1	1	1	1	1	1	1	1	1	1	1	1
CMA8	1	1	1	1	1	1	1	1	1	1	1	3
CMA9	5	5	5	3	5	5	5	5	5	2	5	3
CMA10	3	1	2	1	1	1	1	3	1	4	1	1
CMA11	5	1	2	2	1	1	1	5	1	1	1	1
CMA12	4	1	1	2	1	1	1	5	1	1	1	1
EFD1	1	1	1	1	1	1	1	1	1	1	1	1
EFD2	1	1	1	1	1	1	1	1	1	1	1	5
EFD3	1	1	1	1	1	1	1	1	1	5	1	5
EFD4	5	1	1	1	1	1	1	1	1	1	1	1
EFD5	5	1	1	1	1	1	1	1	1	1	1	5
EFD6	5	1	1	1	1	1	1	1	1	1	5	5
EFD7	3	1	1	1	1	4	1	1	1	1	5	1
EFD8	1	1	1	1	1	1	1	1	1	1	1	5
EFD9	3	3	5	5	1	1	1	5	5	1	1	5
EFD10	3	3	5	5	1	1	1	5	5	1	1	5
EFD11	3	1	1	1	1	5	1	1	1	1	1	5
EFD12	1	1	1	1	1	1	1	1	1	1	1	1
BMN1	5	1	5	1	5	5	1	1	1	5	1	5
BMN2	5	5	5	5	5	5	5	5	5	2	5	5
BMN3	5	5	5	5	5	5	5	5	5	5	5	5
BMN4	5	1	5	1	1	1	1	1	1	3	1	5
BMN5	5	2	2	1	5	1	1	1	2	2	2	1
EFM1	5	1	5	3	1	1	1	1	1	1	1	1
EFM2	1	1	5	1	1	1	1	1	1	1	1	1
EFM3	5	1	5	1	1	5	1	5	1	1	5	1
EFM4	5	1	5	1	1	1	1	5	1	1	5	1
EFM5	1	1	5	5	1	1	1	1	1	1	1	1
EFM6	5	1	1	1	1	1	1	5	1	1	1	1
EFM7	5	1	1	1	1	1	1	3	1	1	1	1
EFM8	3	1	1	1	1	1	1	3	1	1	1	1
EFM9	3	1	1	1	1	1	1	5	1	1	1	1

For CMW sub- practice, the frequency of analysis and monitoring of water usage at schools is at good level. These components are of critical importance in terms of monitoring current water usage behavior and creating water efficiency action plans according to water consumption rates. Performance of CMW8 (Frequency of fire hydrant use in building), CMW9 (Frequency of monitoring excessive water use in laboratories) and CMW11 (Water use monitoring status in the canteen) components are at low performance class. The current application levels of these assessment components should be improved in order to ensure water consumption efficiency in water usage areas at schools. For CMA sub- practice, the current implementation levels of control and supervision practices on water use in open areas at schools are insufficient. The current level of implementation of the components in School8 and School9 schools is close to the average performance class. The insufficient performance of landscape irrigation planning, monitoring of water use, monitoring frequency of use in other water use areas, and utilization of rainwater harvesting in open areas components creates serious pressure on excessive water use or inefficient use of water at schools.

For EFD sub- practice, it is observed that the assessment components are generally in the low performance class at pilot schools. In this category, analysis, monitoring, cost and gain analysis, equipment and team capacity analysis practices within the scope of water efficiency are questioned. It could be said that while the performance of other schools is low or inadequate, the performance of School12 school is generally at quite good level. Especially, the use of water saving equipment (EFD7, EFD8, EFD11) components in water usage areas makes a significant contribution to water efficiency. Low or insufficient levels of these components will result in excessive water usage. Therefore, these components that contribute to water efficiency should be improved. Under the BMN sub- practice, the components of monitoring bills, reducing bills, and analyzing the effects of water saving efforts on bills are assessed. While the components of monitoring the temporal changes in bills and analyzing bill-water usage habits are at

quite good performance class, the other components are at insufficient performance class. These components should be improved to reduce water bills at schools and achieve financial gains. On the other hand, the components under the EFM sub- practice component are generally in the low performance class. In this category, it could be said that while the performance of other schools is low or inadequate, the performance of School8 school is generally good performance class.

The current status (scores) of the assessment components under the main practice of "Control and Maintenance" at the pilot schools are presented in Table 7.

The BCM sub-practice generally covers the inspection, control and maintenance practices of equipment in water usage areas at schools. These components are of critical importance, especially in terms of detecting broken, faulty equipment that causes leakages, repairing it in a short time and ensuring water savings. In this category, components of BCM11 and BCM12 (Creation of monitoring forms for control and repair of equipment in the building) are at low performance class and other components are generally at good or quite good performance class. If the components are at good or quite good performance class, it will contribute to preventing water losses from installations and equipment. The ACM sub- practice generally covers the inspection, control and maintenance practices of equipment in open (landscape) water usage areas. These components are especially quite important in terms of detecting broken, faulty equipment that may cause water loss, repairing it in a short time, and saving water. In this category, components of ACM7 and ACM8 (creation of monitoring forms for checking and repairing equipment) are at low performance class, and other components are generally at good or quite good performance class. The components in this category will contribute to the prevention of water losses from installations and equipment. The WMM sub- practice component covers the control of physical conditions of meters, meter protection and improvement of meter measurement accuracy. These practices are quite important for the meters to measure accurately and to minimize meter errors. In this category, the components are generally at good performance class.

Table 7. Current status of assessment components under the main practice of "s Control and Maintenance" at pilot schools.

Criteria	School1	School2	School3	School4	School5	School6	School7	School8	School9	School10	School11	School12
BCM1	2	1	2	2	1	2	1	2	2	1	2	4
BCM2	1	5	1	5	5	5	2	5	5	1	5	5
BCM3	5	5	5	5	5	5	1	5	5	2	5	5
BCM4	5	5	5	5	5	5	1	5	5	5	5	5
BCM5	5	4	5	5	5	5	1	5	5	5	5	5
BCM6	5	5	5	5	5	5	5	5	5	5	5	5
BCM7	5	5	5	5	1	1	1	5	5	5	5	5
BCM8	5	5	5	5	5	5	5	5	5	4	5	5
BCM9	1	1	1	2	1	1	1	1	1	2	1	5
BCM10	5	5	5	5	5	5	5	5	5	5	5	5
BCM11	1	1	1	1	1	1	1	1	1	1	1	1
BCM12	1	1	1	1	5	1	1	1	1	1	1	1
BCM13	5	3	5	5	3	3	1	5	5	1	3	5
ACM1	2	1	2	2	1	2	1	2	2	1	2	1
ACM2	5	1	3	3	1	5	1	3	3	1	3	1
ACM3	5	4	5	5	1	5	1	5	5	1	5	5
ACM4	5	4	5	5	3	5	2	5	5	2	5	1
ACM5	5	5	5	5	3	5	1	5	5	1	5	5
ACM6	5	5	5	5	5	5	5	5	5	1	5	5
ACM7	1	1	1	2	1	1	1	1	1	1	1	1
ACM8	1	1	1	1	1	1	1	1	1	1	1	1
ACM9	1	1	1	1	1	1	1	1	1	1	1	1
WMM1	5	5	5	5	5	5	5	5	5	2	5	5
WMM2	5	5	5	5	5	5	5	5	5	5	5	5
WMM3	3	1	2	3	4	2	2	2	1	3	3	3
WMM4	5	5	5	5	5	5	5	5	5	5	5	5

Schools are not only institutions where significant amounts of water are consumed, but also environments where awareness, attitudes, and behaviors regarding water usage are shaped. Integrating sustainable water management practices into schools reduces water consumption and losses while improving water literacy for students and staff (Valenzuela-Morales et al., 2022). The water efficiency evaluation system proposed in this study evaluates the current level of implementation of water efficiency practices and events at schools. It is possible to comprehensively assess water efficiency components at schools, identify weaknesses in water efficiency, and determine the components that need priority improvement by implementing this assessment system. Moreover, this system offers a multidimensional approach by considering organizational structure, training and awareness, monitoring and analysis, operational activities, and policy-based management components together. In this respect, the study examines sustainable water management in schools in a holistic way, unlike the one-dimensional water efficiency practices often seen in the literature.

Most of the components in the evaluation system are geared towards determining the level of implementation of water efficiency practices and the rate of student and teacher involvement in these practices. This study also evaluates the level of institutional ownership achieved through the participation of students and staff in activities organized for water efficiency. The findings indicate that sustaining water efficiency activities is possible not through individual effort, but through their implementation across the entire school.

This evaluation system encompasses a very broad information structure, including students, teachers, staff, and parents. This situation, measuring the level of knowledge regarding the importance of water, its efficiency, water footprint, and the journey of water, is effective in identifying lasting solutions. [25] stated that discussing water efficiency with students, staff, and parents has a transformative effect not only within the school but also on societal behavior, contributing to sustainable water management. Therefore, the widespread impact of the study is important in terms of influencing behaviors and forming lasting habits.

Water consumption analysis and monitoring components determine the quantitative water performance of schools and track changes over time, demonstrating the effectiveness of implemented water efficiency activities. International water policies emphasize the need for water consumption measurement and monitoring systems to be effective in water management activities [25]. The literature states that a significant part of water losses in high-consumption buildings are due to leaky faucets, faulty toilets, and unchecked plumbing components [26]. Inspection, control, and maintenance activities include measuring the capacity for facility and equipment management, maintenance and repair, and operational control. These activities contribute to reducing water losses, performing maintenance before breakdowns occur, making water efficiency measurable and creating a dynamic process, determining the management capacity of the installation, and ensuring measurement reliability. In conclusion, the proposed holistic evaluation system plays a significant role in developing water-conscious societies by comprehensively examining water efficiency activities in schools, determining measurable and comparable water efficiency performance scores for schools, and implementing

water efficiency activities on a large scale. The assessment system proposed in this study is tested annually in schools and the improvement and change status of water efficiency practices is monitored.

4 Conclusions

In this study, an assessment system was developed to monitor the current implementation levels of water efficiency practices at schools by considering the components of training and capacity development, maintenance, control, water consumption and efficiency monitoring. The current implementation level of establishment of water efficiency teams and club practices, active participation of students and teachers in practices, the planning, implementation and reporting of practices are insufficient. On the other, teachers' awareness and knowledge levels about water resources, the importance of water, water efficiency and saving, and the journey of water are at good level. However, students' participation in water efficiency training and practices is generally insufficient or at low level. The frequency of analysis and monitoring of water usage is at good level. The practices of analysis, monitoring, cost and gain analysis, equipment and team capacity analysis are generally at low performance level. The inspection, control and maintenance practices of equipment in water usage areas at schools are at good level.

Based on the results of this study, the key recommendations for ensuring water efficiency in schools could be summarized as follows: regularly checking for leaks, replacing old and damaged plumbing systems, implementing rainwater harvesting, and promoting the use of greywater. In addition, suggestions such as setting per capita water consumption targets and creating water efficiency plans in schools, providing water awareness training, conducting regular monitoring and reporting studies, issuing water management certificates for schools, and fostering a culture of water conservation can be added.

The assessment system proposed in this study will make significant contributions to the evaluation, monitoring and sustainable management of current implementation levels of water efficiency practices at schools. It will be possible to monitor water efficiency practices in a holistic and comprehensive manner instead of making limited and narrow-scope evaluations such as analyzing only per capita water consumption in schools. This assessment system will serve as a reference for school administrators, particularly in terms of systematic planning of water efficiency practices at schools and their implementation with broader participation. This system should be implemented regularly at schools on an annual basis and changes should be analyzed. In this way, it is possible to identify the strengths and weaknesses in water efficiency at schools and to monitor the improvement potential of these weaknesses. Thus, unlike the literature, a comprehensive and systematic evaluation will be made rather than just calculating unit water consumption.

The main problems experienced in the implementation of this assessment system are that administrators have difficulty in providing evidence for the assessment components during inspections conducted at schools. Inadequate or incomplete records of practices for assessment components make scoring difficult. In this study, assessment components were defined under three main practices components. The scope and number of these assessment components were determined based on the

literature. In further studies, components such as the use of new technologies and equipment, the use of grey water in landscaping, smart irrigation systems, and smart water fixtures can be taken into consideration. In addition, studies on calculating the general assessment scores of schools and defining the weights of each assessment component will contribute to the development of this assessment system.

5 Acknowledgment

The authors thank Inonu University, Scientific Research Project Funding for their financial support (FYL-2025-3866). This research was supported by TUBITAK (Turkish National Science Foundation) under the Project Number 122M577.

6 Author contribution statement

In this study, Mahmut Fırat and Cansu Bozkurt contributed to improve the idea behind the study. When Furkan Güngör contributed to the establishment of the water efficiency practices at schools and the evaluation of the results, and to the writing of the article. Mahmut Fırat and Cansu Bozkurt controlled the writing, editing, and evaluation of the results.

7 Ethics committee approval and conflict of interest statement

"There is no need to obtain an ethics committee approval in the article prepared". "There is no conflict of interest with any person/institution in the article prepared".

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