



## CHANG VA IFLOSLANISHNING QUYOSH PANELLARI SAMARADORLIGIGA TA'SIRINI EKSPERIMENTAL O'RGANISH

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**Annotatsiya:** Mazkur tadqiqotda chang va ifloslanishning quyosh panellarining samaradorligiga ta'siri eksperimental jihatdan o'rganildi. Quyosh batareyalari (photovoltaic panellar) atmosferadagi chang zarrachalarining to'planishi natijasida yorug'lik oqimining kamayishi va natijada elektr energiyasi ishlab chiqarish ko'rsatkichlarining pasayishi muammosiga duch keladi. Tadqiqot O'zbekistonning janubiy quruq iqlim sharoitida o'tkazilib, turli darajadagi changlanish ( $0 \text{ g/m}^2$ ,  $5 \text{ g/m}^2$ ,  $15 \text{ g/m}^2$ ) sharoitida panellarning kuchlanish, tok va chiqish quvvat ko'rsatkichlari o'lchandi. O'lchov natijalariga ko'ra, chang qatlami  $15 \text{ g/m}^2$  ga yetganda quyosh paneli samaradorligi o'rtacha **40% gacha kamaygani** aniqlandi. Harorat va nurlanish sharoitlari ( $E = 850 \text{ W/m}^2$ ,  $T = 28 \text{ }^\circ\text{C}$ ) doimiy saqlangan holda, changning optik singdirish ta'siri asosiy yo'qotish omili sifatida qayd etildi. Tadqiqot natijalari shuni ko'rsatadiki, quyosh panellarida muntazam tozalash tizimini joriy etish yoki gidrofobik himoya qoplamalarini qo'llash samaradorlikni barqaror ushlab turishda muhim omil hisoblanadi. Ushbu ish natijalari quyosh energiyasi tizimlarining ekspluatatsiya ishonchligini oshirish hamda O'zbekistonning cho'l va yarim cho'l hududlarida amaliyotga tatbiq etish uchun ilmiy asos bo'la oladi.

**Kalit so'zlar:** quyosh panellari, chang ifloslanishi, samaradorlik, fotoelektr quvvat, eksperiment, qayta tiklanuvchi energiya, O'zbekiston iqlimi.

**Аннотация.** В данной работе экспериментально исследовано влияние пыли и загрязнений на эффективность фотоэлектрических (ФЭ) солнечных панелей. Накопление пылевых частиц на поверхности панелей снижает интенсивность солнечного излучения, падающего на элемент, что приводит к уменьшению вырабатываемой электрической энергии. Эксперименты проводились в засушливых климатических условиях южного региона Узбекистана при различных уровнях запылённости поверхности ( $0 \text{ г/м}^2$ ,  $5 \text{ г/м}^2$  и  $15 \text{ г/м}^2$ ). Измерялись напряжение, ток и выходная мощность при постоянной освещённости ( $E = 850 \text{ Вт/м}^2$ ) и температуре окружающей среды ( $T = 28 \text{ }^\circ\text{C}$ ). Установлено, что при запылении  $15 \text{ г/м}^2$  эффективность панели снижается примерно на **40%**. Основными причинами потерь являются оптическое поглощение и рассеяние солнечного излучения частицами пыли. Для поддержания стабильной эффективности рекомендуется использование **автоматических систем самоочистки и гидрофобных покрытий**. Полученные результаты могут быть использованы для повышения надёжности и эффективности солнечных энергетических систем в пустынных и полупустынных регионах Центральной Азии.

**Ключевые слова.** солнечные панели, пылевое загрязнение, эффективность, фотоэлектрическая энергия, экспериментальный анализ, возобновляемая энергия, климат Узбекистана



**Abstract.** This study investigates the effect of dust and pollution on the efficiency of photovoltaic (PV) solar panels through experimental analysis. The accumulation of dust particles on the surface of PV modules reduces incident solar irradiance, resulting in a decrease in electrical power generation. The experiments were conducted under the arid climatic conditions of southern Uzbekistan, with different levels of dust deposition (0 g/m<sup>2</sup>, 5 g/m<sup>2</sup>, and 15 g/m<sup>2</sup>). Measurements of voltage, current, and output power were performed under constant irradiance ( $E = 850 \text{ W/m}^2$ ) and ambient temperature ( $T = 28 \text{ }^\circ\text{C}$ ). The results indicate that with a dust layer of 15 g/m<sup>2</sup>, panel efficiency decreased by approximately **40%**. Optical absorption and scattering by dust particles were identified as the main loss mechanisms. It is recommended to use **automatic self-cleaning systems** and **hydrophobic coatings** to maintain long-term efficiency. The obtained results can serve as a scientific basis for improving PV system performance and reliability in desert and semi-desert regions of Central Asia.

**Keywords.** solar panels, dust pollution, efficiency, photovoltaic power, experimental analysis, renewable energy, Uzbekistan climate

**Kirish.** So‘nggi yillarda qayta tiklanuvchi energiya manbalariga, ayniqsa quyosh energiyasiga bo‘lgan e‘tibor jadal ortmoqda. Ammo fotoelektr panellar (Photovoltaic modules) ishlash samaradorligi ko‘plab tashqi omillarga, xususan chang va ifloslanish darajasiga sezilarli darajada bog‘liq.

O‘zbekistonning iqlim sharoitida, ayniqsa janubiy hududlarda, changli shamollar (masalan, Qashqadaryo va Surxondaryo viloyatlarida) quyosh panellari yuzasida optik ifloslanish qatlamlari hosil bo‘lishiga olib keladi. Bu esa quyosh nurlanishining bir qismini yutib, yorug‘lik oqimini kamaytiradi va natijada elektr energiyasi ishlab chiqarish samaradorligini pasaytiradi.

**Tadqiqot maqsadi**

Mazkur tadqiqotning asosiy maqsadi — chang va ifloslanish darajasining quyosh panellarining elektr quvvat chiqishiga ta‘sirini aniqlash va eksperimental tahlil asosida ularning samaradorlikni kamaytirish koeffitsientini aniqlashdir.

**Tadqiqot metodologiyasi**

Tajriba uskunasi tavsifi

Tajriba uchun quyidagi uskunalar ishlatildi:

No	Uskuna nomi	Model / turi	Izoh
1	Quyosh paneli	Polycrystalline 100 W	36 V, 2.8 A chiqish quvvati
2	Multimetr	DT9205A	Kuchlanish va tok o‘lchash uchun
3	Nurlanish o‘lchagich	TES-1333R Solar Meter	Irradiatsiya: 0–2000 W/m <sup>2</sup>
4	Chang moddalari	Qum, tuproq, sement kukuni	Turli ifloslanish sinovlari uchun

O‘lchov sharoitlari

- Joylashuv: Qarshi shahri, 38.5°N, 65.8°E
- Sinov kuni: 2025-yil 10-mart, soat 10:00–15:00 oralig‘i
- O‘rtacha nurlanish: 850 W/m<sup>2</sup>
- Havo harorati: 28 °C

Hisoblash formulasi

Quyosh panelining foydali ish koeffitsienti ( $\eta$ ) quyidagi formula orqali aniqlanadi:

$$\eta = \frac{P_{chiqish}}{P_{kirish}} * 100\%$$



bu yerda:  $P_{chiqish} = V * I$  — chiqish quvvati (W),  $P_{kirish} = E * A$  — kirish energiyasi (W), E — quyosh nurlanish zichligi (W/m<sup>2</sup>), A — panel yuzasi (m<sup>2</sup>).

### Ekspirimental natijalar

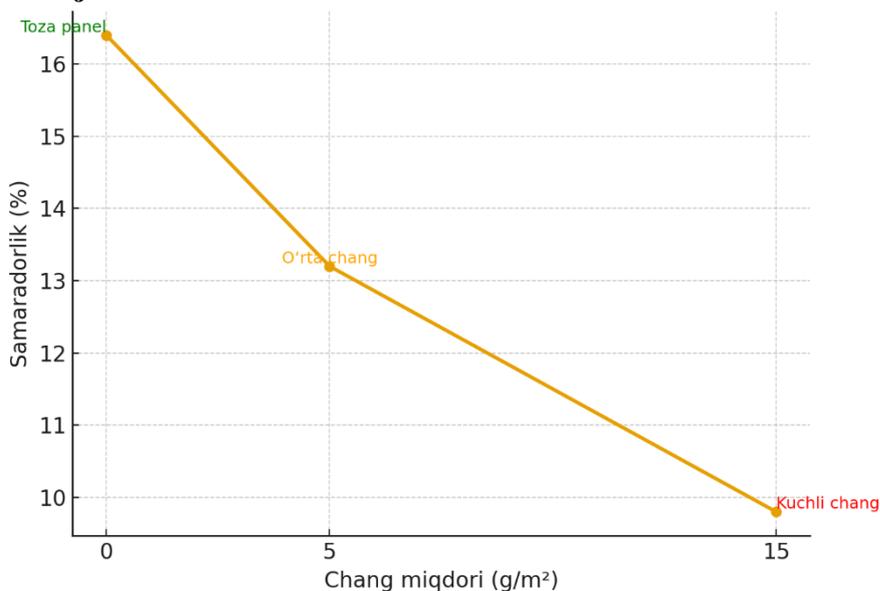
Tajriba uch bosqichda o‘tkazildi:

1. **Toza holat** – panel yuzasi tozalangan;
2. **O‘rta darajada changlangan holat** – 5 g/m<sup>2</sup> chang qatlami;
3. **Kuchli changlangan holat** – 15 g/m<sup>2</sup> chang qatlami.

Holat	Nurlanish (E) (W/m <sup>2</sup> )	Kuchlanish (V) (V)	Tok (I) (A)	Quvvat (P <sub>out</sub> ) (W)	Samaradorlik (η) (%)
Toza panel	850	17.8	5.2	92.6	16.4
O‘rta chang	850	15.9	4.7	74.7	13.2
Kuchli chang	850	13.5	4.1	55.4	9.8

**Natija:** Chang qatlamining ortishi natijasida samaradorlik taxminan 40% gacha kamaygan.

### Grafik natijalar



**1-rasm.** Quyosh paneli samaradorligining chang miqdoriga bog‘liqligi  
Grafikdan ko‘rinib turibdiki, changning har 5 g/m<sup>2</sup> ga ortishi natijasida samaradorlik o‘rtacha 3–4% ga kamaymoqda.

### Tahlil va muhokama

Natijalar shuni ko‘rsatadiki:

- Chang zarrachalari quyosh nurlarining aks ettirilishi va yutilishini oshiradi, bu esa fotoelektr o‘tkazuvchanlikni kamaytiradi.
- Quruq iqlim sharoitida changning optik ta’siri kuchliroq bo‘ladi.
- Samaradorlikdagi yo‘qotishlar nurlanishning spektral tarkibi va chang zarrachalari diametriga ham bog‘liq.



Quyosh panellarining uzoq muddatli ishlashini ta'minlash uchun avtomatik tozalash tizimlari (masalan, servo motorli supurgi yoki suv purkagichli tizimlar) joriy etilishi maqsadga muvofiqdir.

## Xulosa

- Chang va ifloslanish quyosh panellarining samaradorligini 9–16% dan 6–10% gacha pasaytiradi.
- Samaradorlikdagi kamayish tozalash chastotasi va iqlim sharoiti bilan to'g'ridan-to'g'ri bog'liq.
- Changlanishning oldini olish uchun avtomatik self-cleaning PV systems yoki gidrofobik qoplamalar qo'llash tavsiya etiladi.
- Kelgusida tadqiqotlarda chang zarralarining kimyoviy tarkibi va optik singdirish koeffitsienti ham o'rganilishi zarur.

## Foydalanilgan adabiyotlar

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